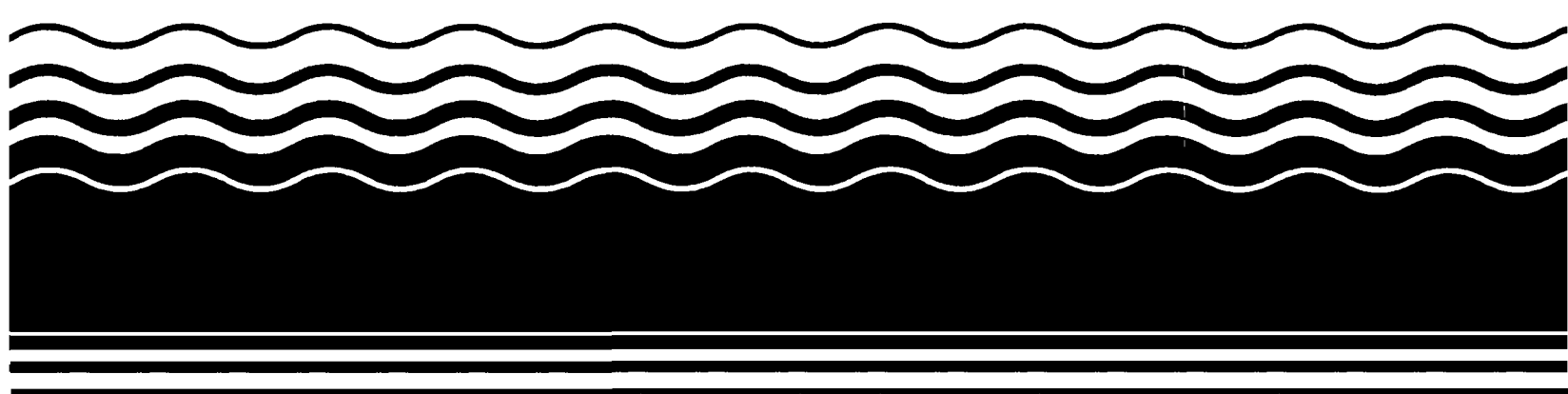




Superfund Record of Decision:

**Lawrence Livermore National
Lab (US DOE), CA**



NOTICE

The appendices listed in the index that are not found in this document have been removed at the request of the issuing agency. They contain material which supplement, but adds no further applicable information to the content of the document. All supplemental material is, however, contained in the administrative record for this site.

REPORT DOCUMENTATION PAGE	1. REPORT NO. EPA/ROD/RO9-92/081	2.	3. Recipient's Accession No.			
4. Title and Subtitle SUPERFUND RECORD OF DECISION Lawrence Livermore National Lab (USDOE), CA First Remedial Action - Final	5. Report Date 08/05/92		6.			
	8. Performing Organization Rept. No.		10. Project/Task/Work Unit No.			
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9. Performing Organization Name and Address		13. Type of Report & Period Covered 800/000				
		14.				
12. Sponsoring Organization Name and Address U.S. Environmental Protection Agency 401 M Street, S.W. Washington, D.C. 20460		15. Supplementary Notes PB93-964504				
16. Abstract (Limit: 200 words) The 800-acre Lawrence Livermore National Lab (LLNL) site is a multidisciplinary research facility located in Livermore, California. The site is owned by the Department of Energy (DOE) and operated by the Regents of the University of California. Land use in the area is predominantly industrial with an urban area to the west and agricultural lands to the east of the LLNL facility. Wetlands at the site consist of three small areas associated with culverts that channel runoff from the surrounding area into Arroyo Las Positas at the northern perimeter of the site. About 10,000 people use the ground water, which is blended from several downtown Livermore municipal wells, as their primary drinking water supply. The LLNL site was converted from agricultural and cattle ranch land by the Navy in 1942, who used the site until 1946 as a training facility and for aircraft assembly and maintenance. Solvents, degreasers, and paints were routinely used. Between 1946 and 1950, the site was used as a naval reserve command training center, and in 1951, the Atomic Energy Commission (AEC) began using the property as a weapons design and physics research laboratory. In 1977, DOE took over responsibility of the site. Investigations for suspected ground water contamination at LLNL were prompted by the state beginning in 1984, when (See Attached Page)						
17. Document Analysis a. Descriptors Record of Decision - Lawrence Livermore National Lab (USDOE), CA First Remedial Action - Final Contaminated Media: Sediment, gw Key Contaminants: VOCs (benzene, carbon tetrachloride, chloroform, PCE, TCE), metals (chromium, lead), radioactive materials (tritium) b. Identifiers/Open-Ended Terms c. COSATI Field/Group						
18. Availability Statement	19. Security Class (This Report) None	21. No. of Pages 70				
	20. Security Class (This Page) None	22. Price				

Abstract (Continued)

perchloroethylene was discovered in the domestic supply well of a nearby property. LLNL began supplying bottled water to local residents whose domestic wells had been affected by solvents migrating from the LLNL facility. Between 1985 and 1987, the LLNL continued the ground water investigations, which revealed that releases of hazardous materials had occurred at the LLNL site during the 1940's. Also in the post-Navy era, localized spills, leaking tanks, surface impoundments, and landfills contributed VOC, FHC, metal, and tritium contamination to ground water and unsaturated sediments. Prior to 1985, LLNL conducted two significant removal actions. From 1982 to 1983, four former pits in the Taxi Strip Area in eastern LLNL were excavated and backfilled; in 1984, a former landfill was also excavated and backfilled. This ROD addresses a final remedy for the contaminated sediment and ground water at the LLNL site. An additional potential source of hazardous materials, the Trailer 5475 East Taxi Strip Area, has been identified and is being investigated. If additional public health or environmental risks from this or other sources are identified, this ROD may be augmented to address any additional necessary actions. The primary contaminants of concern affecting the sediment and groundwater are VOCs, including benzene, PCE, TCE, chloroform, and carbon tetrachloride; metals, including lead and chromium; and the radioactive material, tritium.

The selected remedial action for this site includes treating unsaturated sediment at LLNL onsite using vacuum-induced venting to extract contaminants in vapor form from the sediment and treating the vapors by catalytic oxidation and/or activated carbon; pumping water at 24 initial locations to contain and remediate the ground water plume using both existing and new extraction wells; constructing seven onsite facilities (A-G) to treat the extracted ground water, and each treatment system will be designed to treat the specific combinations of compounds, including using ultraviolet/oxidation at facilities A, B, E, and F to treat VOCs; using air-stripping based technologies at facilities C, D, and G to treat the chloroform and carbon tetrachloride; employing ion exchange at facility D to remove chromium; and using granular activated carbon (GAC) at treatment facility F to remove lead, if necessary; using GAC at all facilities to remove contaminants from air streams generated during treatment; onsite recharging or reusing of the treated water at the LLNL site; and monitoring ground water until EPA, DOE, and the state regulatory agencies agree that cleanup is complete. The estimated present worth cost for this remedial action is \$104,100,000, which includes an annual O&M cost of \$21,585,000 for 50 years.

PERFORMANCE STANDARDS OR GOALS: Chemical-specific sediment and ground water clean-up goals are the more stringent SDWA MCLs and California State MCLs and include benzene 1 ug/l, PCE 5 ug/l, TCE 5 ug/l, lead 15 ug/l, total chromium 50 ug/l, tritium less than 20,000 picocuries per litre, chloroform 100 ug/l, total trihalomethanes 100 ug/l, and carbon tetrachloride 0.5 ug/l. Sediment of the unsaturated zone will be remediated only if it is predicted that it would result in concentrations above an MCL if allowed to migrate into the ground water. Unsaturated zone remediation will be complete when modeling shows that contaminants will no longer migrate and cause ground water to exceed MCL. The CWA (NPDES) discharge limits for these chemicals will also be met if effluent waters from the remedial treatment are discharged to ditches or arroyos onsite.



U.S. Department Of Energy
San Francisco Operations Office, Oakland, California 94612

Lawrence Livermore National Laboratory
University of California Livermore, California 94551



UCRL-AR-109105

**Record of Decision
for the Lawrence Livermore
National Laboratory
Livermore Site**

July 15, 1992



Environmental Protection Department
Environmental Restoration Division

UCRL-AR-109105

**Record of Decision
for the Lawrence Livermore
National Laboratory
Livermore Site**

July 15, 1992

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1. The Declaration

1.1. Site Name and Location

The Lawrence Livermore National Laboratory (LLNL) Livermore site, located at 7000 East Avenue, Livermore, California, is a research and development facility owned by the U.S. Department of Energy (DOE) and operated by the University of California. LLNL was placed on the U.S. Environmental Protection Agency's (EPA) National Priorities List (NPL) in 1987. Currently, about 10,000 people use ground water blended from several downtown Livermore municipal supply wells as their primary drinking water supply. Contaminants from LLNL are currently about 1.6 miles from these supply wells. U.S. EPA, in conjunction with the California Department of Toxic Substances Control (DTSC) and the California Regional Water Quality Control Board (RWQCB), oversees LLNL's investigations and cleanup activities in accordance with Section 120 of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended.

1.2. Statement of Basis and Purpose

This decision document presents the selected remedial actions for the LLNL Livermore site, in Livermore, California, which were chosen in accordance with CERCLA, as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), and, to the extent practicable, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). This decision document is based on the administrative record for this site.

The U.S. EPA, the RWQCB, and the DTSC of the California Environmental Protection Agency, formerly the California Department of Health Services (DHS), concur with the selected remedies.

1.3. Assessment of Site

The identified compounds of concern, if not addressed by the selected remedies or other considered measures, may present a potential risk to public health as discussed in the Proposed Remedial Action Plan (PRAP) for the site.

1.4. Description of the Selected Remedy

The Feasibility Study (FS) evaluated many potential remedies for the LLNL site. Those remedies were divided into two general groups, according to whether the chemical contaminants are in ground water or in unsaturated sediment (i.e., sediment above the water table where pore spaces are only partially filled with water). Three alternatives were evaluated for the ground water plume, and two remedies were evaluated for the unsaturated zone (i.e., the interval above the water table where pore spaces are only partially filled with water).

The selected remedy for ground water is Remedial Alternative No. 1 from the FS, which includes:

- Pumping water at 18 initial locations to contain and remediate the ground water plume. Water will be pumped from one or more wells at each of these locations using existing monitor and extraction wells, along with new extraction wells. The initial well locations will be chosen to prevent any contaminants, primarily volatile organic compounds (VOCs), from escaping from the current plume area in concentrations above their Maximum Contaminant Levels (MCLs). To enable more rapid remediation, wells will also be placed in all areas with higher concentrations [i.e., greater than about 100 parts per billion (ppb) VOCs or fuel hydrocarbons (FHCs)]. The initial 18 locations will be augmented when field data indicate that new pumping locations will speed the cleanup.

- Constructing about seven onsite facilities (A to G) to treat the extracted ground water. Each treatment system would be designed to treat the specific combination of compounds in the associated extraction wells.
- Using ultraviolet (UV)/oxidation-based remediation technology to treat VOCs at Treatment Facilities A, B, and E, and FHCs and VOCs at Treatment Facility F. Treatment Facilities C, D, and G would use air-stripping-based technology, which is more effective on the higher concentrations of specific compounds in the area of those facilities (chloroform, carbon tetrachloride, Freon 113, and 1,1,1-trichloroethane). Treatment Facility D will employ ion exchange to remove chromium, and Treatment Facility F will use granular activated carbon (GAC) to remove lead, if necessary.

The selected remedy for treating the unsaturated zone is Remedial Alternative No. 1 from the FS. This alternative includes using a process called vacuum-induced venting to extract the contaminants in vapor form from the unsaturated sediments, and treating the vapors by catalytic oxidation and activated carbon.

The selected remedies address the principal concerns at the LLNL site by removing contaminants in ground water and soil vapor and treating them at the surface to levels protective of human health and the environment.

This Record of Decision (ROD) applies to all known contaminants in ground water and unsaturated sediment originating from activities at the LLNL site. An additional potential source of hazardous materials (i.e., the Trailer 5475/East Taxi Strip Area) was identified after completion of the PRAP on the LLNL site. If future investigations identify additional public health or environmental risks from this or other potential sources, this ROD may be augmented through CERCLA/SARA and the NCP to address any additional action.

1.5. Statutory Determinations

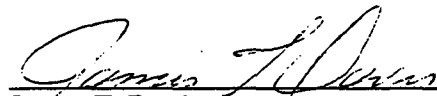
The selected remedies are protective of human health and the environment, comply with Federal and State requirements that are legally applicable or relevant and appropriate to the remedial action, and are cost-effective. The remedies utilize permanent solutions and alternative treatment technology; to the maximum extent practicable, and satisfy the statutory preference for remedies that employ treatment that reduces toxicity, mobility, or volume as a principal element. Because these remedies may result in hazardous materials remaining onsite above health-based levels until cleanup is complete, a review will be conducted within 5 years after commencement of remediation to assure that the remedies continue to provide adequate protection of human health and the environment.



Daniel W. McGovern
Regional Administrator, EPA Region IX

8-5-92

Date



James T. Davis
Acting Manager, DOE San Francisco Field Office

7/23/92

Date

2. Decision Summary

2.1. Site Name, Location, and Description

LLNL is a multidisciplinary research facility owned by DOE and operated and managed by the Regents of the University of California under contract with DOE. LLNL is located at 7000 East Avenue in southeastern Alameda County, approximately 3 miles east of the downtown area of Livermore, California (Fig. 1). The LLNL site, including the adjacent buffer zone, comprises approximately 800 acres (Fig. 2). The site is heavily developed with large-scale experimental research and support facilities. About 223 storage tanks exist onsite, 46 of which are underground tanks that currently store hazardous materials. A stormwater drainage retention basin roughly 800 feet by 300 feet in size is situated near the center of LLNL. This basin was recently lined to prevent infiltration of ponded surface water.

The LLNL site land surface slopes approximately 1% to the northwest. Hills of the Diablo Range flank the site to the south and east. The site is underlain by several hundred feet of complexly interbedded alluvial and lacustrine sediments.

Ground water beneath the site is partly within the Spring and Mocho I hydrologic subbasins (DWR, 1974). Depth to ground water at the site varies from about 120 feet in the southeast corner to about 25 feet in the northwest corner. Ground water about 2 miles west of LLNL is used for municipal supply in downtown Livermore. Ground water about 1,000 feet south of East Avenue and about 1,000 feet west of Vasco Road and south of East Avenue is used for domestic and agricultural irrigation. Two intermittent streams, the Arroyo Seco and the Arroyo Las Positas, traverse the area (Fig. 2) and recharge the ground water system during wet periods.

Land immediately north of the LLNL site is zoned for industrial use. To the west, the land use is zoned for high-density urban use. Sandia National Laboratories (SNL), Livermore are located south of the site (Fig. 2) in an area zoned for industrial development. The area east of LLNL is zoned for agriculture and is currently used as pasture land [LLNL Remedial Investigation (RI), Thorpe *et al.*, 1990].

As reported in the Draft Environmental Impact Statement and Environmental Impact Report for LLNL and Sandia National Laboratories, Livermore (DOE and University of California, 1992), no threatened or endangered species are present at the LLNL Livermore site. Wetlands are very limited at the Livermore site and consist of three small areas associated with culverts that channel runoff from the surrounding area into Arroyo Las Positas at the northern perimeter of the site (DOE and University of California, 1992).

2.2. Site History and Summary of Enforcement Activities

2.2.1. Site History

The LLNL site was converted from agricultural and cattle ranch land by the U.S. Navy in 1942. The Navy used the site until 1946 as a flight training base and for aircraft assembly, repair, and overhaul. Solvents, paints, and degreasers were routinely used during this period. Between 1946 and 1950, the Navy housed the Reserve Training Command at the site. In 1950, the Navy allowed occupation of the site by the Atomic Energy Commission (AEC), which formally received transfer of the property in 1951. Under the AEC, the site became a weapons design and basic physics research laboratory. In 1952, the site was established as a separate part of the University of California Radiation Laboratory. Responsibility for the site was transferred from AEC to the Energy, Research, and Development Administration in 1975. In 1977, responsibility for LLNL was transferred to the DOE, which is currently responsible for the site. In addition to weapons research, LLNL programs have been established in biomedicine, energy, lasers, magnetic fusion energy, and environmental sciences. Details of the site history and the

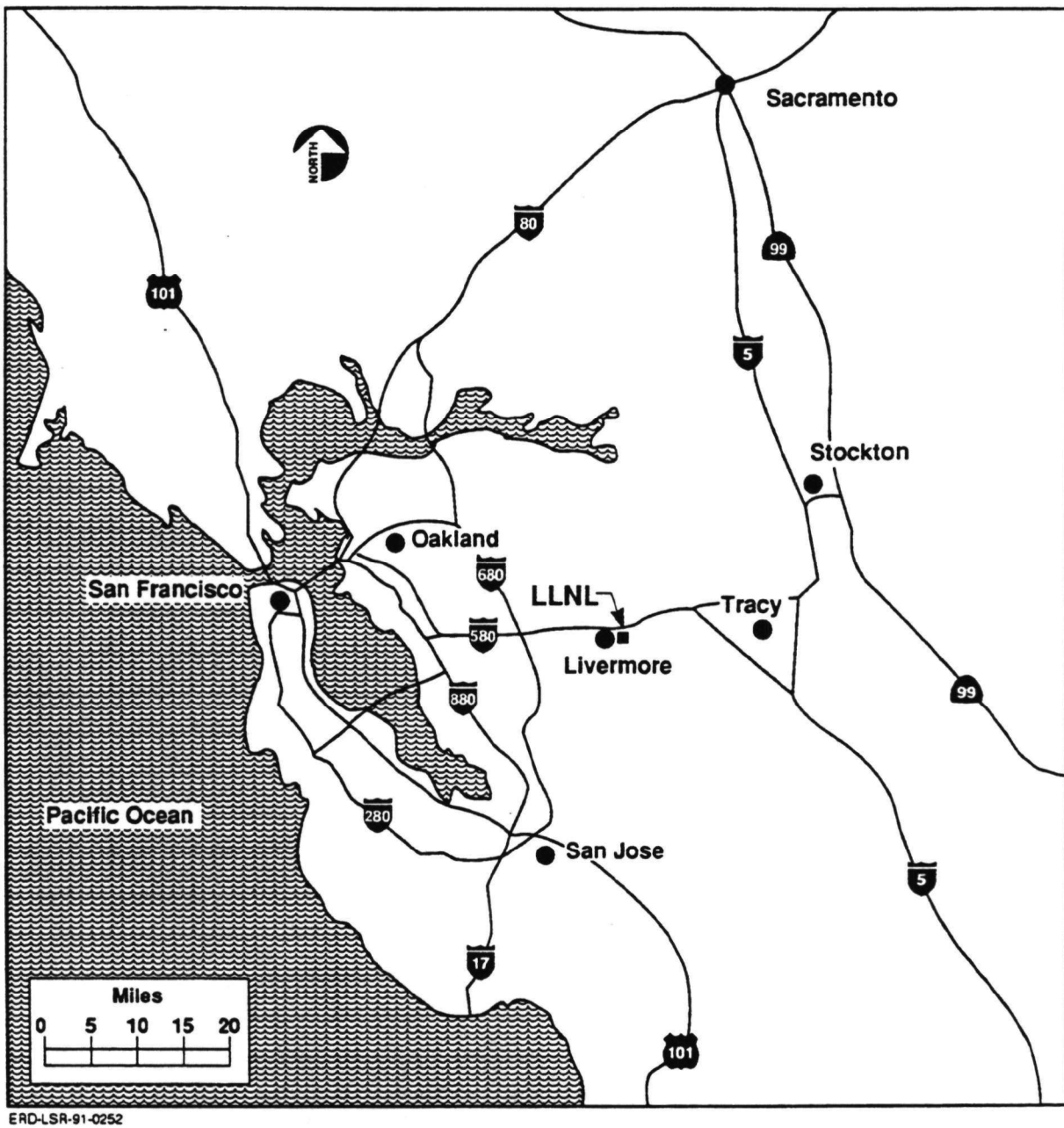


Figure 1. Location of the LLNL Livermore site.

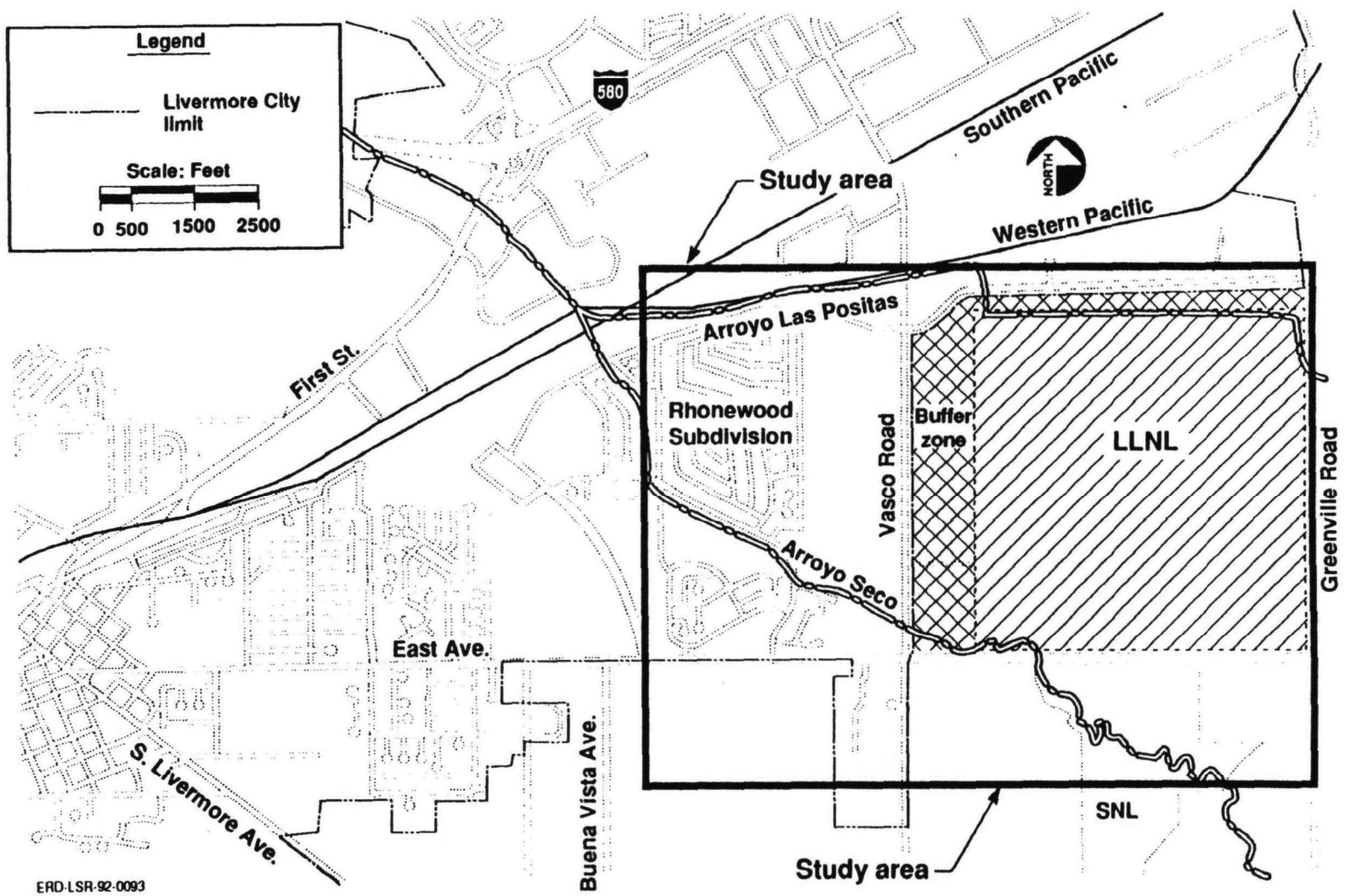


Figure 2. The LLNL site and surrounding area.

use, storage and disposal of hazardous materials are presented in the Remedial Investigation (RI) (Thorpe *et al.*, 1990).

2.2.2. Summary of Enforcement Activities

The LLNL site was in operation prior to the enactment of the Resource Conservation and Recovery Act of 1976.

The first regulatory order for the LLNL ground water problem was a compliance order issued in 1984 by the California Department of Health Services (DHS) (now the Department of Toxic Substances Control of the California Environmental Protection Agency). This order required LLNL to investigate ground water quality and to supply bottled water to local residents whose domestic wells had been affected by solvents migrating in ground water from LLNL. At the time this order was issued, the ground water investigation was already underway, and bottled water had been supplied to those local residents since December 1983. All private wells affected by the solvents were permanently sealed by LLNL between 1985 and 1989. In 1985, the RWQCB issued Waste Discharge Requirements to define the vertical and lateral extent of ground water contamination, and to allow discharge of ground water during the investigation. Between 1986 and 1991, the RWQCB issued four Waste Discharge Orders and two Site Cleanup Orders for the LLNL site. Currently, two RWQCB Orders are in effect at LLNL. Order No. 88-075 allows discharge of treated water from pilot Treatment Facility A to a recharge basin south of East Avenue. Order No. 91-091 allows discharge of treated ground water from LLNL treatment facilities to ditches and arroyos, and recharge of treated ground water via infiltration trenches and recharge wells.

Between 1985 and 1987, the RWQCB was the lead regulatory agency for the LLNL ground water investigation. In 1987, LLNL was added to the National Priorities List, as amended. In November 1988, DOE, U.S. EPA, DTSC, and RWQCB signed a Federal Facility Agreement (FFA), which named DOE as the overall lead agency and the U.S. EPA as the lead regulatory agency.

LLNL conducted two significant removal actions prior to 1985. Four former pits in the Taxi Strip Area in eastern LLNL were excavated and backfilled in the winter of 1982-83 under the oversight of the RWQCB. In 1984, a former landfill was excavated and backfilled with oversight by the DHS.

In May 1990, LLNL issued the *CERCLA Remedial Investigations Report for the LLNL Livermore Site* (RI) (Thorpe *et al.*, 1990). In December 1990, the *CERCLA Feasibility Study for the LLNL Livermore Site* (FS) (Isherwood *et al.*, 1990) was issued, and, in October 1991, the *Proposed Remedial Action Plan for the LLNL Livermore Site* (PRAP) (Dresen *et al.*, 1991) was submitted. The Notices of Availability for the PRAP were published in three local newspapers on October 18, 1991, and again on November 19 and 20, 1991, when the comment period on the PRAP was extended. These documents, and all other documents that are the basis for selecting the cleanup remedies for the LLNL site, are contained in the Administrative Record for LLNL, which is located at the LLNL Visitors Center. The LLNL Visitors Center can be accessed from the Greenville Road (east) entrance to LLNL.

2.3. Highlights of Community Participation

2.3.1. Background

The LLNL ground water problem was brought to the attention of the local community in December 1983, when perchloroethylene (PCE) was first discovered in the domestic supply well of a former rental property northeast of the intersection of Vasco Road and East Avenue. LLNL's immediate action was to sample private wells and deliver bottled water to nearby residents whose wells had been affected. LLNL periodically surveyed these households, located

south, southwest and west of LLNL, to ensure that residents were receiving bottled water to meet their water needs, and that the water was arriving in a timely manner. Subsequently, LLNL provided free municipal (City of Livermore) water hookups to the affected households. LLNL also began a regular private well sampling program. In all cases, testing results were (and continue to be) shared with the residents either through telephone calls, personal visits, or follow-up letters that include written sampling results.

In May 1988, LLNL and DOE held a general information meeting for the community on the ground water investigation with key Ground Water Project staff. In addition, LLNL and DOE have responded and continue to respond to requests from the public for information.

LLNL staff conducted interviews between April and July of 1988 with approximately 45 individuals, groups, and agencies to investigate their concerns and information needs regarding the Livermore site cleanup. The results of these interviews formed the basis for the Community Relations Plan that LLNL issued in May 1989. Copies of this plan were made available to the public, and placed in the information repositories located at the Livermore Public Library and at the LLNL Visitors Center.

The specific objectives of the LLNL Livermore Site Community Relations Program are to:

- Continue providing interested members of the community with timely information about technical activities and findings.
- Provide ongoing opportunities for two-way communication between the LLNL Ground Water Project and the community.
- Establish effective communication with local elected and administrative officials.
- Remain alert to the community's needs and concerns about the Ground Water Project and other LLNL activities.

2.3.2. Community Involvement

The LLNL Community Relations Program communicates with the public through six primary methods:

1. Meetings with a Community Work Group (CWG).
2. Distribution of a quarterly newsletter called the *Ground Water Project Update* and fact sheets.
3. Maintenance of the two information repositories.
4. Support to those responsible for offsite water samples and water level surveys.
5. Setting up tours and responding to general information requests.
6. Meeting with members of the public, including the Technical Advisors hired by a local community group as part of the EPA Technical Assistance Grant (TAG) Program.

Each of these activities is described below.

2.3.2.1. Community Meetings

LLNL established the CWG in 1988 to provide an ongoing forum to advance understanding of technical issues and project decisions, community interests, and the Superfund process throughout the course of the LLNL Ground Water Project. The group is composed of private individuals, representatives of a local community group, and representatives of U.S. EPA, RWQCB, and DTSC. The CWG meets quarterly, and sometimes more often, depending on the status of the technical and regulatory aspects of the Ground Water Project. LLNL has worked to

distribute and explain technical information to the CWG and identify key issues of concern. LLNL has taken steps to respond to those concerns by providing additional information, making changes to certain aspects of the project or, when changes are not possible, by providing the reasons for not taking the proposed action. CWG meetings are open to the public.

A public meeting on the PRAP was held on November 6, 1991, as required by the CERCLA process. About 80 people attended the meeting. The Notice of Availability for the PRAP was published in three local newspapers on October 18, 1991. The public comment period on the PRAP extended from October 18 to December 18, 1991. All comments on the PRAP are addressed in Attachment A, the Responsiveness Summary, to this ROD.

2.3.2.2. Ground Water Update and PRAP Fact Sheet

Distributed on a quarterly basis, the *Ground Water Project Update* reflects LLNL's desire to regularly inform the community about the Ground Water Project. This multipage fact sheet is distributed to more than 1,800 individuals and organizations. The first edition was published in June 1989.

A fact sheet on the PRAP was distributed in October 1991 prior to the opening of the public comment period on the PRAP. The fact sheet was written specifically to facilitate community understanding of the PRAP.

2.3.2.3. Information Repositories

LLNL established two information repositories in 1989 to provide locations for interested members of the public to review project-related reports. One repository is located at the Livermore Public Library, 1000 South Livermore Avenue, the other is at the LLNL Visitors Center on Greenville Road. The Visitors Center also contains the Administrative Record, which is comprised of all the documents that form the basis for LLNL's final cleanup plan.

2.3.2.4. Support to Offsite Well Monitoring Program

The Ground Water Project arranges sampling times and locations that are convenient to those residents and businesses affected by the offsite well monitoring program. Followup includes mailing a letter that explains the significance of the results.

2.3.2.5. Tours and General Information Requests

Tours have been conducted on request for interested members of the public and for the press. In 1991, tours were conducted of the pilot study treatment units for CWG members and the press. On LLNL Family Day of 1990, special sitewide tours for a number of interested groups were conducted. Requests for general information are handled by community relations staff or appropriate LLNL staff.

2.3.2.6. Contact with Technical Assistance Grant Advisors

A local citizens group hired two technical advisors under a grant approved by U.S. EPA and funded by the DOE as part of the TAG program. The technical advisors have attended CWG meetings and have submitted comments to LLNL regarding project reports. LLNL provided copies of project documents, conducted tours, responded to the advisors' queries, and held an all-day meeting with these advisors in July 1991. LLNL also provided one of the advisors with work space and resources for a week to review project-related documents.

2.3.2.7. Future Community Involvement

DOE and LLNL are committed to maintaining community involvement throughout the cleanup. If desired by the local community, DOE/LLNL will continue to support a CWG. CWG meetings may be used to brief TAG advisors, if desired. Progress of the cleanup will also be

reported to the regulatory agencies and the community in *Monthly Progress Reports*. As required by CERCLA, the Community Relations Plan will be updated after the ROD is signed.

2.4. Scope and Role of Response Actions

The remedial alternatives described in the FS (Isherwood *et al.*, 1990) and the PRAP (Dresen *et al.*, 1991) are summarized in this ROD and address VOCs, FHCs, chromium, and lead in ground water, and FHCs and VOCs in sediment above the water table (the unsaturated zone). In addition, tritium has been detected locally in the soil and ground water, but as described in Section 4.2.1 of the PRAP, tritium at LLNL is self-remediating via natural decay and does not require cleanup. There is no significant way for people to be exposed to the contaminants in the unsaturated zone at LLNL except by migration of the contaminants to the ground water.

This ROD addresses all known ground water and unsaturated zone contamination and any resultant human health and environmental risks, and incorporates the results of LLNL pilot studies. Amendments to this ROD may be made in the future to address significant new or additional contaminants and/or source areas or other unforeseen conditions.

The cleanup objectives for all contaminants originating at LLNL are to:

1. Prevent future human exposure to contaminated ground water and soil.
2. Prevent further migration of contaminants in ground water.
3. Reduce contaminant concentrations in ground water to levels below MCLs, and reduce the contaminant concentrations in treated ground water to levels below State discharge limits (Table 1).
4. Prevent migration in the unsaturated zone of those contaminants that would result in concentrations in ground water above an MCL.
5. Meet all discharge standards of existing permits for treated water, and to treat vapor so that there are no measurable atmospheric releases from treatment systems.

The selected remedial alternatives will achieve these cleanup objectives and address all of the principal concerns at the site by removing the hazardous compounds from the ground water and subsurface soil, when warranted, and treating them at the surface at about seven onsite facilities. Ground water extraction will contain contaminant plumes, stop further migration of contaminants in ground water, and prevent any human exposure to them via water wells. The ground water treatment facilities will use different remediation technologies appropriate for the different influent contaminants and will be designed to reduce contaminant concentrations in the treated ground water to levels below established State discharge standards.

Ground water extraction and treatment will continue until the Federal and State agencies agree that the remediation standards have been met. The target objective is to reduce the concentrations in the ground water after cleanup to levels below MCLs (Table 1).

The ground water remediation standards in Table 1 are the lower of the Federal or State MCLs, and apply to the concentrations remaining in the ground water after remediation is complete. Ground water cleanup is complete when samples taken anywhere in the plume demonstrate that the remediation standards have been achieved. The discharge limits in Table 1 apply to the effluent water from treatment systems that may be discharged to ditches or arroyos. Although some discharge limits are lower than MCLs, remediation will continue until the remediation standards are met.

Volatile contaminants in the unsaturated zone will be removed by extracting them in vapor, which will be treated onsite. Atmospheric emissions from treatment systems will comply with

Table 1. Remediation standards and State discharge limits for compounds of concern in ground water at the LLNL site.

Constituent	Concentration limit for drinking water ^a		Pre-remediation concentration range at LLNL, March 1990–March 1991 (ppb)	Discharge limit ^b for treated water (ppb)
	Federal MCL (ppb)	California MCL (ppb)		
PCE	5	5	<0.1–1,050	4
TCE	5	5	<0.1–4,800	5
1,1-DCE	7	6	<0.5–370	5
cis-1,2-DCE	70	6	<0.5–24	5 (total 1,2-DCE)
trans-1,2-DCE	100	10	<0.5–1	5
1,1-DCA	—	5	<0.5–60	5
1,2-DCA	5	0.5	<0.1–190	5
Carbon tetrachloride	5	0.5	<0.1–91	5
Total THM ^c	100 ^c	100 ^c	<0.5–270	5
Benzene	5	1.0	<0.1–4,600	0.7
Ethyl benzene	700	680	<0.2–610	5
Toluene	1,000	—	<0.5–4,200	5
Xylenes (total)	10,000	1,750 ^d	<0.5–3,700	5
Ethylene dibromide	0.05	0.02	<0.1–51	0.02
Total VOCs	—	—	up to 5,808	5
Chromium ⁺³	50 (total Cr) ^e	50 (total Cr)	<5–150 (total Cr)	50 (total Cr)
Chromium ⁺⁶	50 (total Cr) ^e	50 (total Cr)	<10–140	11
Lead	15 ^f	50	<2–10	5.6
Tritium ^g	20,000 pCi/L	20,000 pCi/L	<200–33,100	(h)

^a Human receptor. The more stringent concentration limits on this part of the table are shown in a larger typeface to illustrate that LLNL will comply with the most stringent requirements.

^b From National Pollutant Discharge Elimination System (NPDES) Permit No. CA0029289 (revised 8/1/90) and RWQCB Order No. 91-091. Of the LLNL compounds of concern, VOC-specific State discharge limits exist in RWQCB Order No. 91-091 only for PCE (4 ppb), benzene (0.7 ppb), and ethylene dibromide (0.02 ppb). Other VOCs listed in this table are included in the 5 ppb total VOC limit. Discharge limits for metals differ slightly according to discharge location.

^c Total trihalomethanes (THMs); includes chloroform, bromoform, chlorodibromomethane, and bromodichloromethane (California Drinking Water Requirement).

^d MCL is for either a single isomer or the sum of the ortho, meta, and para isomers.

^e National Interim Primary Drinking Water Regulation for total chromium is presently 50 ppb, but will increase to 100 ppb in July 1992. No MCLs exist for Cr⁺³ or Cr⁺⁶.

^f National Primary Drinking Water Regulation Enforceable Action Level (Federal Register, volume 56, number 110, June 7, 1991, p. 26460).

^g The RI shows that ground water in the one well that currently exceeds the tritium MCL will be naturally remediated long before it migrates offsite.

^h There is currently no NPDES discharge limit for tritium. LLNL will use the MCL for tritium as the discharge limit.

Bay Area Quality Management District (BAAQMD) standards. Contaminants in the unsaturated zone will be remediated only if it is predicted that they would result in concentrations above an MCL if allowed to migrate into the ground water. Unsaturated zone remediation will be complete when modeling shows that contaminants will no longer migrate to ground water and create concentrations in the ground water above an MCL.

As part of the additional source investigations that are in progress, evaluations of the transport of VOCs and non-VOCs from the unsaturated zone to the ground water will be conducted. These investigations may identify areas where additional soil and ground water remediation is necessary. Results of these investigations will be summarized in *Monthly Progress Reports* for review by the regulatory agencies and the public.

Treated ground water will be recharged via wells, the LLNL recharge basin, and local arroyos, and/or used for LLNL landscape irrigation or in LLNL cooling towers, to conserve water resources.

2.5. Site Characteristics

Initial releases of hazardous materials occurred at the LLNL site in the mid- to late 1940s when the site was the Livermore Naval Air Station (Thorpe *et al.*, 1990). There is also evidence that localized spills, leaking tanks and impoundments, and landfills contributed VOCs, FHCs, lead, chromium, and tritium to ground water and unsaturated sediment in the post-Navy era. A screening of all environmental media showed that ground water and unsaturated sediment are the only media that require remediation (Thorpe *et al.*, 1990). The identified compounds that exist in ground water at various locations beneath the site at concentrations above drinking water standards are:

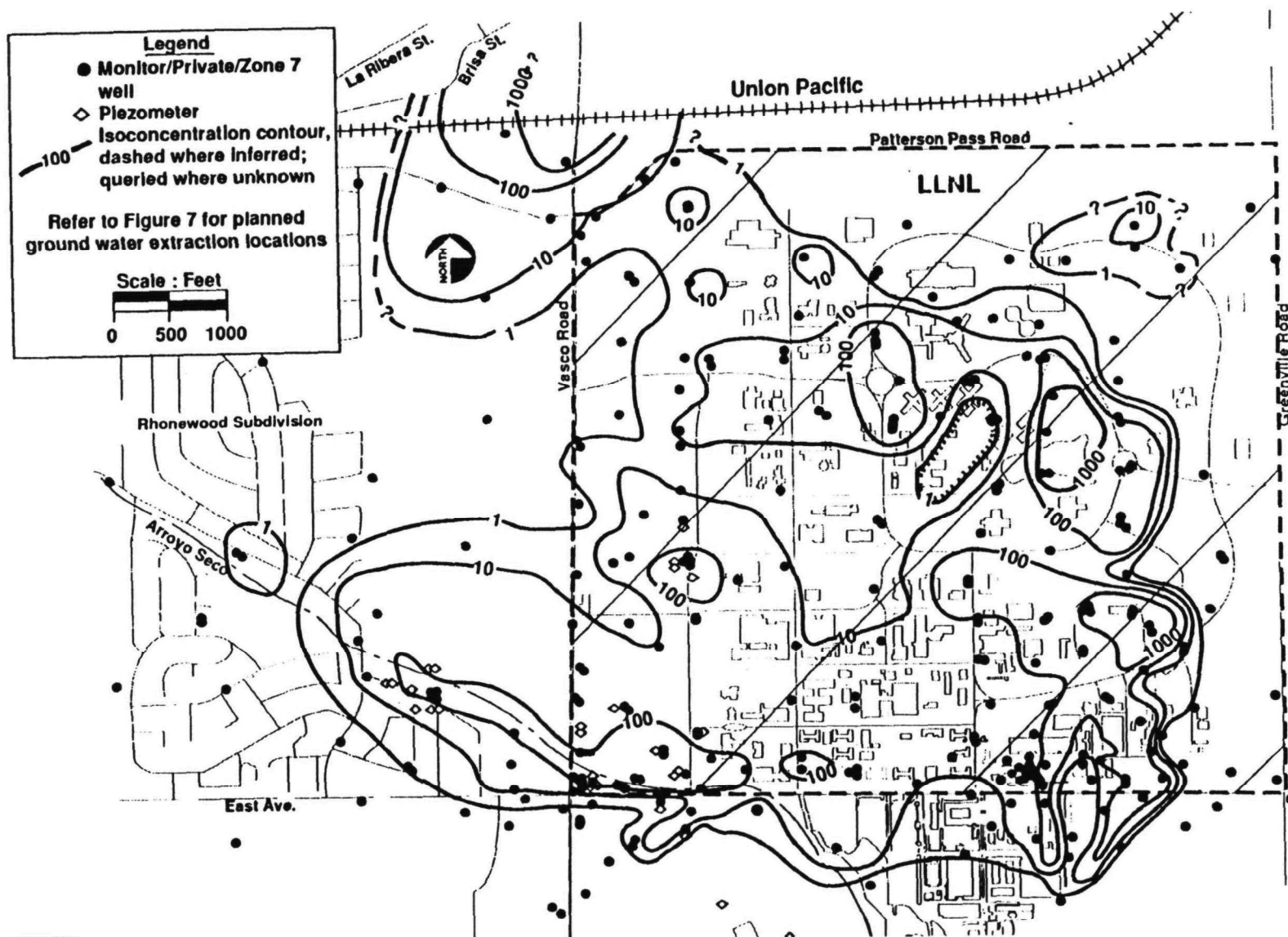
1. The VOCs trichloroethylene (TCE), perchloroethylene (PCE), 1,1-dichloroethylene (1,1-DCE), 1,2-dichloroethylene (1,2-DCE), 1,1-dichloroethane (1,1-DCA), 1,2-dichloroethane (1,2-DCA), carbon tetrachloride, and the trihalomethane (THM) chloroform.
2. FHCs (leaded gasoline), including benzene, ethylbenzene, toluene and ethylene dibromide.
3. Chromium and lead.
4. Tritium.

The quality of data for these compounds was considered in the selection of the remedies for the LLNL site in accordance with the *LLNL Quality Assurance Project Plan* (QAPP, Rice, 1988).

2.5.1. VOCs

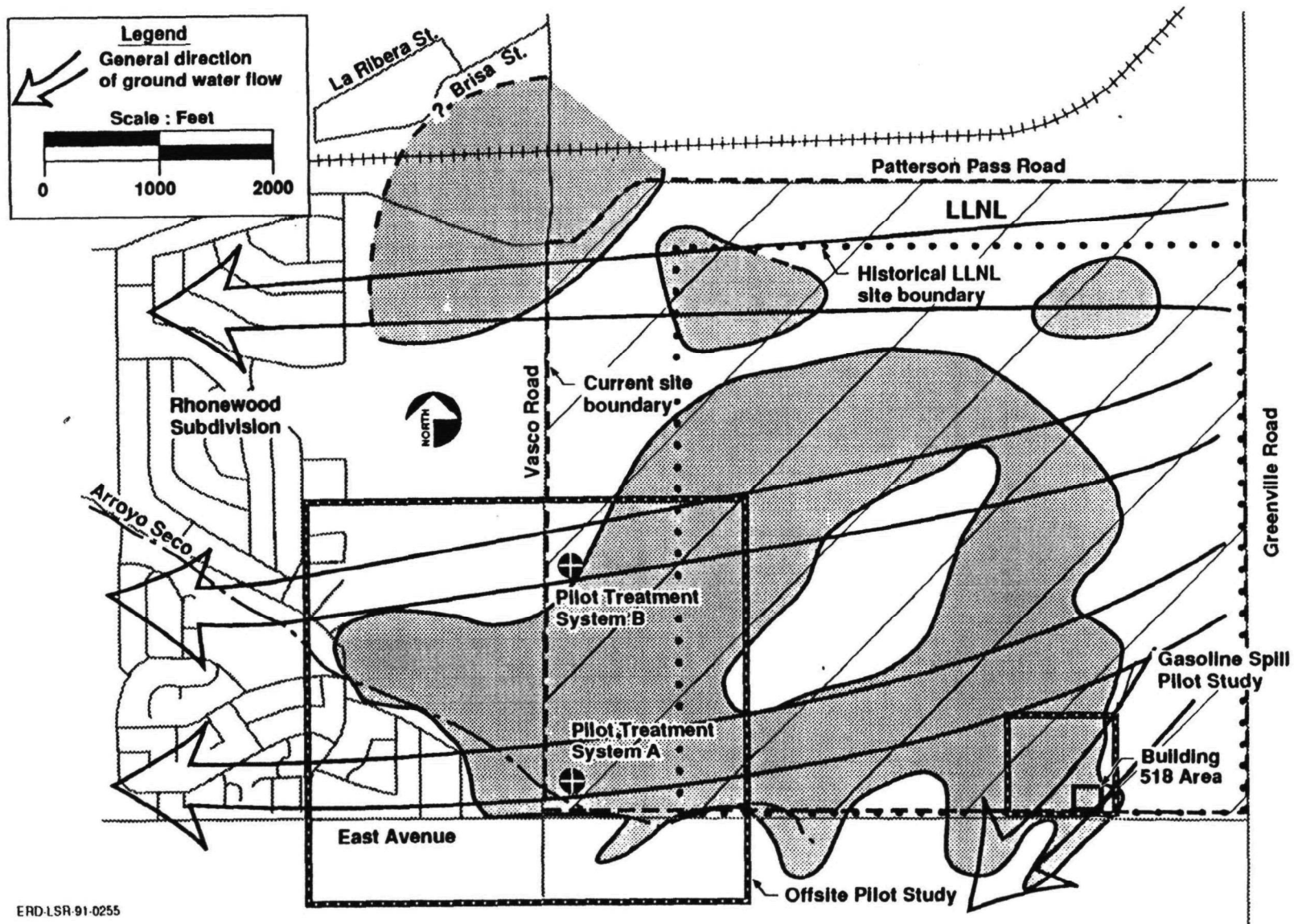
The VOCs in ground water beneath LLNL occur in relatively low concentrations that underlie about 85% of the LLNL site, over a total area of about 1.4 square miles (Fig. 3). The calculated total volume of undiluted VOCs in ground water is less than 200 gallons. The vertical thickness of the ground water VOC plumes varies from about 30 to 100 feet, and VOCs are seldom found below a depth of about 200 feet. VOCs are relatively mobile in ground water and migrate at a rate of about half the velocity of ground water. TCE and PCE are the predominant VOCs in the study area, and are currently present locally in concentrations up to 4.8 and 1.1 parts per million (ppm) respectively (1992 data). However, the higher concentrations are localized, and total VOC concentrations exceed 1 ppm in ground water from only 10 out of a total of more than 300 wells. The distribution of VOCs in ground water exceeding MCLs is shown in Figure 4. The VOCs and chromium in ground water in the vicinity of the Patterson Pass-Vasco Road intersection appear to originate on private property northwest of the LLNL site as discussed in Iovenitti *et al.* (1991) and

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Figure 3. Isoconcentration contour map of total VOCs in ground water.



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Figure 4. Area where one or more VOCs in ground water equals or exceeds Federal or California maximum contaminant levels (MCLs).

Hoffman (1991a). This offsite area will be investigated by the potentially responsible parties under RWQCB order. If LLNL is found to be the source of chromium in this area, LLNL will incorporate this area into the remedial design.

Chemical data from boreholes drilled at the locations of suspected VOC releases at LLNL indicate that generally low residual VOC concentrations (less than 100 parts per billion [ppb]) are present in unsaturated sediments. The calculated total volume of undiluted VOCs in the unsaturated zone is less than 100 gallons. Computer modeling indicates that downward movement of VOCs above the water table is not likely to result in ground water VOC concentrations exceeding MCLs for drinking water, except at the Building 518 Area in the southeast corner of the site (Isherwood *et al.*, 1990). The Trailer 5475 Area is also being evaluated for possible cleanup.

In the Building 518 Area, VOCs (predominantly TCE) reach a maximum concentration of about 6 ppm at a depth of 20 feet. These VOCs are believed to have originated from surface spills or leaking drums in the post-Navy era. Recent investigation in the Trailer 5475 Area (also called the East Taxi Strip Area) in eastern LLNL indicate that remediation may be necessary pending additional subsurface investigations and modeling. Total VOC concentrations (predominantly TCE) reach a maximum concentration in unsaturated soil of about 5 ppm in that area. These VOCs originate from former landfills and surface impoundments.

2.5.2. Fuel Hydrocarbons

FHCs occur almost exclusively where a leak of roughly 17,000 gallons of leaded gasoline occurred from a U.S. Navy-era underground fuel tank in the southern part of the site (Fig. 5). Although some gasoline constituents are relatively mobile in ground water, FHCs in ground water have not migrated more than about 500 feet from the leak point due to the very slow ground water movement in the area (Thorpe *et al.*, 1990). Within this area, total FHC concentrations in ground water range from 0.001 to 16 ppm, and benzene concentrations range from less than 0.0001 to about 4 ppm. Ethylene dibromide has been detected in nine Gasoline Spill Area monitor wells above the MCL in concentrations from 0.0001 to 1.3 ppm. FHCs are not present in ground water beneath a depth of about 150 feet.

Prior to withdrawal of fuel vapor by vacuum-induced venting as part of a Gasoline Spill Area pilot study, up to 11,000 ppm total FHCs and 4,800 ppm aromatic hydrocarbons were detected in the unsaturated sediments beneath the former fuel tank. Virtually all FHCs in the unsaturated zone are about 50 feet radially from the leak point.

2.5.3. Metals

Metals above MCLs are present in only a few locations. Chromium in ground water exceeds the MCL in 16 wells scattered in the northwest, central, and southwest parts of the study area and near Arroyo Seco (Fig. 6). The maximum chromium concentration in ground water in the LLNL study area is 160 ppb, in the northwestern corner of the site. Chromium in the LLNL area sediments and ground water appears to have originated naturally and from some LLNL site activities. At LLNL, chromate solutions were used in cooling towers as corrosion inhibitors from approximately 1958 to 1970. Blowdown from the cooling towers was released to the storm drain system, but neither the exact quantity of releases nor the chromium content of the water are known. According to anecdotal information, storm runoff caused the blowdown to flow northerly before infiltrating into the ground near the West Traffic Circle. In addition, naturally occurring chromium deposits have been mined in the hills southeast of LLNL. As described in Section 2.5.1, chromium in ground water northwest of LLNL appears to originate on private property and will be investigated by others (i.e., the potentially responsible parties).

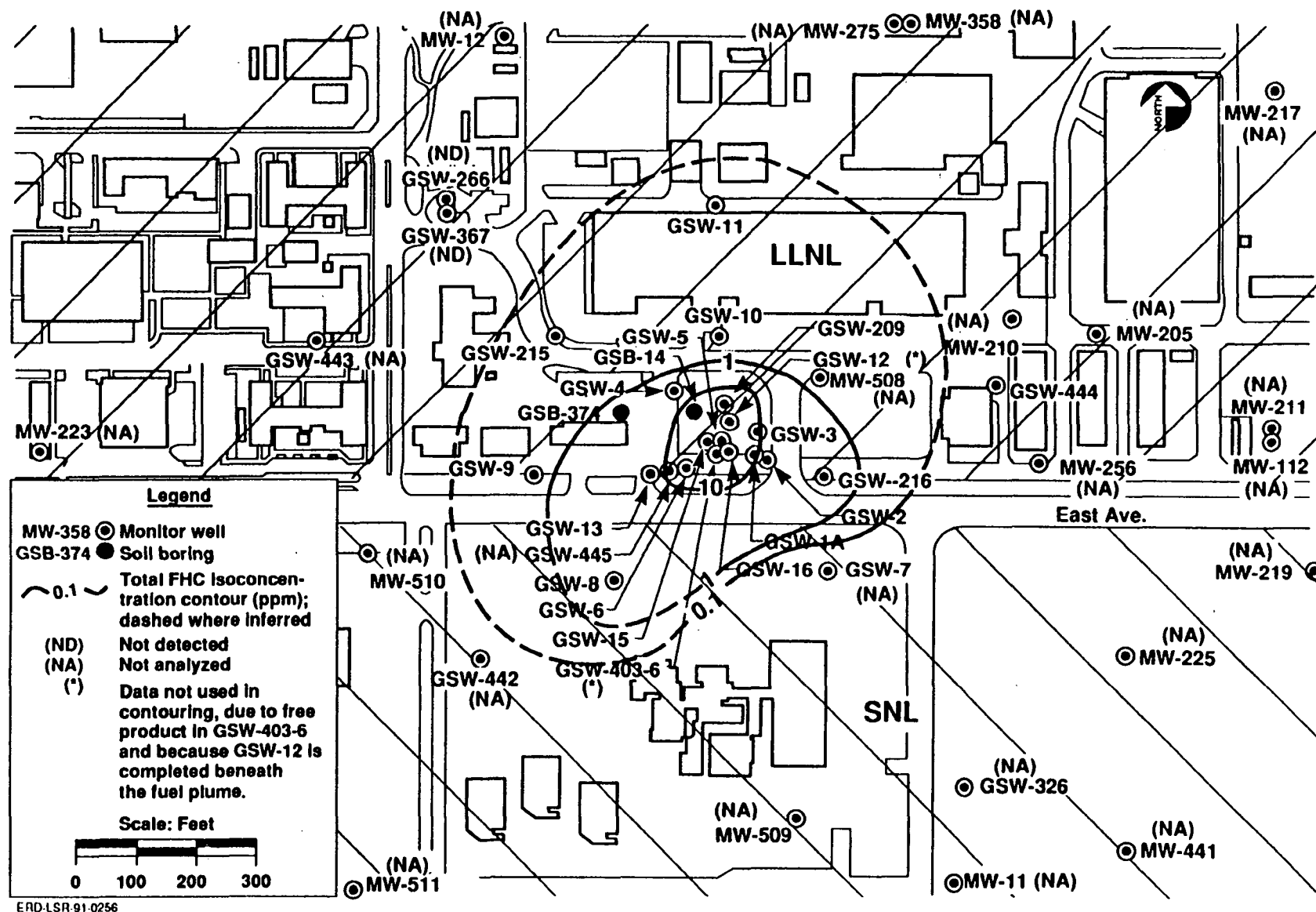
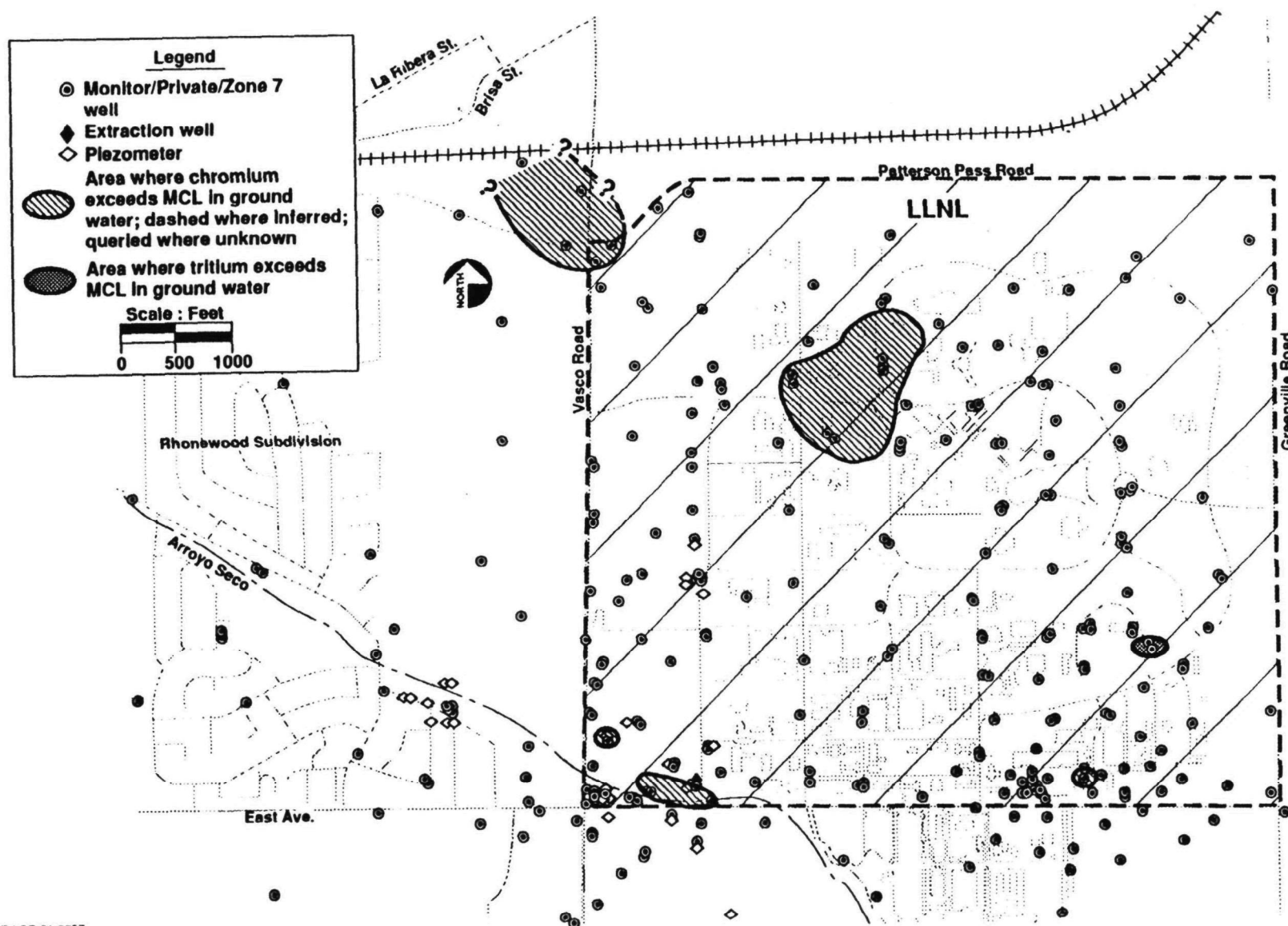


Figure 5. Isoconcentration contour map of total fuel hydrocarbons (FHCs) in ground water, Gasoline Spill Area, March 1989. All areas that exceed fuel hydrocarbon MCLs are encompassed by the 0.1-ppm contour.

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Figure 6. Areas that exceed the maximum contaminant level (MCL) for total chromium (50 ppb) and tritium (20,000 picocuries per liter) in ground water.

Recent analyses indicate lead is above the 15 ppb remediation standard in only two wells, both in the Gasoline Spill Area, at a maximum concentration of 38 ppb. Lead has a low potential for migration in both the saturated and unsaturated zones because it binds strongly to sediment. This low migration rate and limited extent, indicate that lead at LLNL does not pose a health threat. If, however, lead is found in ground water above the remediation standard, it will be remediated.

2.5.4. Tritium

Tritium in ground water has historically exceeded its MCL (20,000 picocuries per liter [pCi/L]) in only two wells, MW-206 and MW-363, both in the southeast part of the LLNL site. Currently, water from only MW-206 exceeds the tritium MCL (Fig. 6). This tritium was released to the subsurface in former, nearby evaporation ponds, is localized and well defined, and the affected ground water is not used for drinking water. Although tritium migrates at the same rate as ground water, ground water modeling indicates that by the time the affected ground water moves offsite in the absence of active remediation, tritium concentrations would be reduced to concentrations below drinking water standards by natural decay (tritium has a 12.3-year half-life). Therefore, no pathway to humans exists for the observed tritium in ground water. The tritium is effectively self-remediating via natural decay. Ground water will continue to be monitored for tritium to track its distribution and concentrations over the duration of the cleanup.

Recent investigations have identified additional areas where tritium concentrations in unsaturated sediments at LLNL are significantly elevated. These include the Building 514, Eastern Landing Mat Storage, West Traffic Circle, Building 292, and Old Salvage Yard Areas. However, the tritium activity in ground water in these areas is well below the 20,000 pCi/L MCL. The only potentially significant transport pathways to human populations for this tritium are inhalation and skin absorption of tritiated water from direct soil evaporation or from water taken up by plants and released to the air by transpiration from plant leaves. Most of the areas where tritium has been detected are paved with asphalt, thereby limiting potential evaporation from soil and further downward migration by infiltration of rainwater. Elevated tritium levels in transpired water have been measured in isolated areas at LLNL. Screening-level calculations have been performed by LLNL using the standard EPA model AIRDOS-EPA and very conservative assumptions that maximize the calculated dose. These calculations indicate that any potential dose from the measured tritium in soil would not exceed 0.01% of the 10-millirem/year Federal dose standard (Macdonald *et al.*, 1990). Additional information regarding the distribution, concentration, toxicity, mobility, potential routes of migration, and potential exposed populations of all LLNL compounds of concern can be found in the RI, the Baseline Public Health Assessment (BPHA) (Layton *et al.*, 1990), and Sections 2.1 and 2.6 of this ROD.

2.6. Summary of Unremediated Site Risks

As part of the RI report (Thorpe *et al.*, 1990), the BPHA (Layton *et al.*, 1990) was conducted to estimate the potential future health risks if contaminants in ground water and sediments originating from LLNL were not remediated. Evaluation of a no-action scenario is a requirement of the NCP, 40 CFR section 300.430(e)(6), to represent a baseline condition. In addition, a risk assessment was conducted as part of the FS (Isherwood *et al.*, 1990) to estimate the potential public health risks if the concentrations of VOCs in ground water were reduced to their respective MCLs. These and other assessments of potential risks are summarized in the PRAP (Dresen *et al.*, 1991) and below. Details of the risk assessments are contained in the RI and FS.

2.6.1. Human Health Risks

The LLNL risk assessment consisted of several steps:

- Identifying the contaminants of concern (see Section 2.5 of this ROD).

- Identifying the media through which exposure may occur.
- Assessing the exposure.
- Assessing the toxicity of each contaminant.
- Quantifying the risk.

Each of these is discussed below.

2.6.1.1. Contaminant Identification

2.6.1.1.1. Media of Concern

The primary medium through which public exposure to LLNL contaminants may occur is ground water. Air is also a medium of concern for contaminants that may volatilize from contaminated soil or ground water. The public is not directly exposed to contaminated soils because no offsite surficial soils contain significant concentrations of contaminants originating from LLNL. Contaminated onsite surficial soils were evaluated as a potential medium of concern. However, a screening analysis of the risks resulting from potential onsite exposure to contaminated soils has shown these risks are insignificant (Layton *et al.*, 1990; Hoffman, 1991b; Macdonald *et al.*, 1991). Therefore, surficial soils are not a medium of concern for the LLNL site.

2.6.1.1.2. Contaminants of Concern

A screening analysis was conducted to determine which substances and exposure pathways are potentially important from the perspective of potential adverse health effects. A statistical analysis of thousands of water and soil samples estimated the relative abundance of particular contaminants in the study area (Layton *et al.*, 1990). TCE, PCE, and chloroform account for an estimated 91% of the total amount of VOCs dissolved in the LLNL-area ground water. Of the remaining VOCs, the most hazardous are carbon tetrachloride and 1,1-DCE, which were used to represent the potential adverse effects of the remaining 9% of the VOCs. Nearly 60% of the mass of the remaining 9% of VOCs is 1,1-DCE. These compounds were used to estimate the public health risks resulting from the offsite migration and domestic use of contaminated ground water. According to the U.S. EPA, PCE, TCE, chloroform, and carbon tetrachloride are classified as B2 carcinogens, which are described as "probable human carcinogens indicated by sufficient evidence in animals and inadequate or no evidence in humans" (U.S. EPA, 1989a). 1,1-DCE is classified as a Class C carcinogen by the U.S. EPA (possible human carcinogen).

Other contaminants in soil and ground water include benzene at the Gasoline Spill Area, tritium, and inorganic substances, such as chromium, lead, nitrate, sulfate, and manganese. A screening analysis of the transport and fate of benzene indicates that benzene or other gasoline-related contaminants (toluene, xylene isomers, and ethylbenzene) are not likely to reach detectable concentrations west of LLNL. Similarly, tritium continues to undergo radioactive decay with a 12.3-year half-life such that by the time ground water containing elevated levels of tritium would migrate to the western LLNL boundary in the absence of remediation, concentrations would be within background levels. As stated in Section 2.5.4, LLNL plans to monitor tritium in ground water over the life of the cleanup.

As discussed in a letter to the regulatory agencies (Hoffman, 1992), there is strong evidence that the lead in LLNL ground water is naturally occurring. Furthermore, as described in Section 2.5.3, it appears that the migration potential for lead is very low, and its occurrence above the remediation standard is very limited. Several inorganic substances, including chromium, nitrate, sulfate, and manganese, occur in ground water in concentrations exceeding regulatory limits in various monitor wells, sporadically located onsite and offsite. Except perhaps for chromium, which has been used in LLNL cooling towers, the observed concentrations appear to reflect background levels of these constituents in ground waters in the Livermore Valley.

2.6.1.1.3. Concentrations of Chemicals of Concern Used in the Risk Assessment

To assess the ground water exposure pathway, migration of the five VOCs of concern (PCE, TCE, chloroform, carbon tetrachloride, and 1,1-DCE) was simulated using the January-September 1988 concentrations as initial conditions. These concentrations range from the various detection limits up to a maximum of 6 ppm for TCE in the Building 518 Area.

2.6.1.2. Exposure Assessment

2.6.1.2.1. Exposure Pathways

The only potential exposure pathway for present and future offsite populations is use of contaminated well waters. For domestic water uses, the potential exposure pathways are ingestion of drinking water, inhalation of volatile substances, and entry through the skin. For irrigation uses, the potential exposure pathways are inhalation of volatilized chemicals from sprinklers, and ingestion of foods from crops or home gardens irrigated with water containing the chemicals of concern. Exposure from contact with surface water runoff or sediment in local arroyos that receive drainage waters from the LLNL site is not a pathway of concern, because no chemicals of concern have been detected in downstream drainage channels near LLNL, and ground water does not discharge to streams near LLNL. The most important offsite exposure pathways with regard to health risk are those that result from domestic well water use from offsite wells (Thorpe *et al.*, 1990).

2.6.1.2.2. Potentially Exposed Population

As described in the BPHA and in Section 2.6.1.1.1 above, there are no significant onsite exposure pathways for LLNL site contaminants. Prior to any soil excavation at LLNL, the existing soil cleanup data are reviewed and maps of known or suspected contamination are consulted to determine whether additional sampling needs to be conducted prior to excavation. If no samples have been previously collected in a given area, preconstruction sampling is performed before excavation begins. If contamination is found, appropriate safety and disposal practices are overseen by the LLNL Hazards Control Department.

The only potentially exposed offsite population consists of residents who use ground water that has migrated from LLNL. In the assessments of risk for the LLNL site, a future residential-use scenario was not considered because it is unlikely that transfer of ownership of the site from DOE would occur in the foreseeable future. No change in ownership of the LLNL Main Site or any portion thereof, or notice pursuant to Section 120 of CERCLA, will relieve DOE of its obligation to clean up contamination resulting from DOE activities, or any future contamination resulting from DOE activities at LLNL. In addition, no change of ownership of the site or any portion thereof will be consummated by DOE without provision for continued maintenance of any containment system, treatment system, monitoring system, or other response action(s) installed or implemented under terms of the LLNL FFA.

2.6.1.2.3. Exposure Point Concentration Estimates

To assess the potential future health risks of the known contaminants in ground water, the movement of VOCs from their current distribution was simulated with a model. A semianalytical model of contaminant transport and fate in ground water was used that considers advection, dispersion, retardation, and degradation. The BPHA contains details on the assumptions and the parameters used in the model.

To address uncertainty inherent in all contaminant migration calculations, two scenarios were investigated, one called "best-estimate" and the other "health-conservative." The health-conservative scenario uses parameter values and assumptions that yield exposures that are very unlikely to be exceeded. U.S. EPA prefers using the most conservative of the health-conservative scenarios (footnote "b," Table 4, Section 2.6.1.4.3) as their estimate of the potential

health risk from the LLNL site. The best-estimate simulations use parameter values that are considered to be the most likely or the most representative, based on existing knowledge of the LLNL ground water system and contaminant properties. Best-estimate simulation assumes no human exposure to the ground water until it reaches the currently used municipal supply wells in downtown Livermore because no private wells are currently contaminated and administrative control limits the potential for domestic well installation into a contaminated zone. The administrative control consists of notification by Zone 7, the local water agency, that a proposed new well is in or near the contaminant plume.

2.6.1.2.4. Exposure Frequency and Duration

The exposure period for the offsite public for any exposure pathway of concern was assumed to be a 70-year lifetime. For offsite exposures to contaminated ground water, the fate and transport model was used to calculate maximum 70-year average concentrations in ground water at existing and potential offsite wells. It was assumed that the exposed population uses ground water as its sole source of domestic water for this continuous 70-year period. These and other assumptions were used to estimate the total daily uptake of each chemical of concern in milligrams of chemical per kilogram body mass per day (mg/kg-day).

2.6.1.3. Toxicity Assessment

2.6.1.3.1. Cancer Potency Factors

Cancer potency factors (CPFs) have been developed by U.S. EPA to estimate excess lifetime cancer risks associated with exposure to potentially carcinogenic chemicals. CPFs, expressed in units of (mg/kg-day)⁻¹, are multiplied by the estimated intake of a potential carcinogen, in mg/kg-day, to provide an upper-bound estimate of the excess lifetime cancer risk associated with exposure at that intake level. The term "upper bound" reflects the conservative estimate of the risks calculated from the CPF. Use of this approach makes underestimation of the actual cancer risks highly unlikely. CPFs are derived from the results of human epidemiological studies or chronic animal bioassays to which animal-to-human extrapolation and uncertainty factors have been applied (e.g., to account for the use of animal data to predict the effects on humans).

CPFs for the LLNL chemicals of concern are listed in Table 2. In conformance with EPA methodology, cancer potencies are based on applied, rather than metabolized, doses.

Table 2. Cancer potency factors for carcinogenic chemicals of concern (Layton *et al.*, 1990).

Chemical	Oral cancer potency (mg/kg-d) ⁻¹	Inhalation cancer potency (mg/kg-d) ⁻¹
Carbon tetrachloride	0.13	0.13
Chloroform	0.0061	0.0081
1,1-DCE	0.6	1.2
PCE	0.051	0.0033
TCE	0.011	0.017

2.6.1.3.2. Reference Doses for Noncarcinogens

Reference doses (RfDs) have been developed by EPA for indicating the potential for adverse health effects from exposure to chemicals exhibiting noncarcinogenic effects. RfDs, which are expressed in units of mg/kg-day, are estimates of lifetime daily exposure levels for humans, including sensitive individuals. Estimated intakes of chemicals from environmental media (e.g., the amount of a chemical ingested from contaminated drinking water) can be compared to the RfD. RfDs are derived from human epidemiological studies or animal studies to which

uncertainty factors have been applied (e.g., to account for the use of animal data to predict the effects on humans). These uncertainty factors help ensure that the RfDs will not underestimate the potential for adverse noncarcinogenic effects to occur.

Reference doses for the LLNL chemicals of concern are listed in Table 3.

Table 3. Reference doses for noncarcinogenic chemicals of concern (Layton *et al.*, 1990).

Chemical	Reference dose (mg/kg-d)
Carbon tetrachloride	0.0007
Chloroform	0.01
1,1-DCE	0.009
PCE	0.01
TCE	NA

NA= not available.

2.6.1.4. Risk Characterization

2.6.1.4.1. Carcinogenic Risks

The information from the preceeding steps was combined to determine if an excess health risk would exist if the site were not remediated. Excess lifetime cancer risks are determined by multiplying the intake level with the CPF. These risks are probabilities that are generally expressed in scientific notation (e.g., 1×10^{-6} or $1\text{E-}6$). An excess lifetime cancer risk of 1×10^{-6} indicates that, as a plausible upper bound, an individual has a one in one million chance of developing cancer as a result of site-related exposure to a carcinogen over a 70-year lifetime under the specific exposure conditions at a site.

Tables A-1 and A-2 in Appendix A summarize the estimated cancer risks for offsite exposure to ground water for both the best-estimate and health-conservative exposure scenarios for PCE, TCE, 1,1-DCE, chloroform, and carbon tetrachloride. Under the best-estimate exposure scenario (Table A-1), the greatest incremental cancer risk is seven in ten million (7×10^{-7}), which is associated with a well 2 miles west of the LLNL site that is in the path of the plume containing the highest concentrations of 1,1-DCE. Under the health-conservative exposure scenario (Table A-2), the incremental cancer risks are on the order of one in one thousand (10^{-3}) to one in one million (10^{-6}) for all wells. The highest predicted risk, two in one thousand (2×10^{-3}), is for a hypothetical well about 250 feet west of the LLNL site. However, no such wells have been constructed to date or are planned for installation prior to cleanup. The most conservative of the health-conservative scenarios (i.e., the one with the 2×10^{-3} incremental risk) is the scenario prescribed by EPA for the LLNL site.

2.6.1.4.2. Potential for Noncarcinogenic Effects

Potential noncarcinogenic effects of a single contaminant in a single medium is expressed as the hazard quotient (HQ) (or the ratio of the estimated intake derived from the contaminant concentration in a given medium to the contaminant's reference dose). By adding the HQs for all contaminants within a medium or across all media to which a given population may be reasonably exposed, the hazard index (HI) can be estimated. If only one compound is involved, then the HQ is equivalent to the HI. If the HI value is greater than 1.0, exposure could result in adverse health effects. The HI provides a useful reference for gauging the potential significance of multiple contaminant exposures within a single medium or across media.

Tables A-3 and A-4 in Appendix A summarize the estimated HQ's for offsite exposure to ground water for both the best-estimate and health-conservative exposure scenarios for the

chemicals of concern at LLNL. Under the best-estimate exposure scenario (Table A-3), the greatest HQ is 1.4×10^{-3} , which is for a hypothetical well 2 miles west of the LLNL site in the path of the plume containing the highest concentrations of carbon tetrachloride. Under the health-conservative exposure scenario (Table A-4), the HQ's are on the order of 10^{-2} to 10^{-1} for all wells. The highest predicted HQ (0.8) is for a hypothetical well that is 250 feet west of the LLNL site.

2.6.1.4.3. Combined Carcinogenic Risks and Hazard Indices

The maximum theoretical excess cancer risks for a hypothetical, no-remediation scenario, based on the assumption that an individual will use well water for a 70-year (lifetime) period, are presented in Table 4. The maximum additional cancer risk associated with the best-estimate scenario in Table 4 means that the cancer risk from a lifetime exposure to VOCs (PCE, TCE, chloroform, and carbon tetrachloride) in well water derived from a downtown Livermore municipal supply well could be as high as 7 in 10 million (7×10^{-7}), using EPA assessment methods. This means that each individual that consumes 2 liters (about 2 quarts) of this water each day for 70 years would increase his or her risk of developing cancer by 7 in 10 million above the normal 1 in 4 cancer risk for Americans (U.S. EPA, 1989a). The HI associated with the best-estimate scenario is far below 1.0, indicating exposure at the predicted concentrations would not produce any adverse health effects from noncarcinogens (see the RI, Thorpe *et al.*, 1990, for details).

Table 4. No-remediation-scenario cancer risk and hazard index (HI) values using the EPA methodology^a (U.S. EPA, 1989a).

No-remediation scenario	Risk of cancer	HI
Best-estimate	7×10^{-7}	1.6×10^{-3}
Health-conservative ^b	2×10^{-3}	1
Health-conservative ^c	1×10^{-3}	1

^a See Isherwood *et al.* (1990) for an alternative method of computing the risk of cancer and HI.

^b Based on potential monitor well drilled 250 feet west of LLNL.

^c Based on receptor wells drilled in downtown Livermore.

Under the health-conservative no-remediation scenario, the maximum additional cancer risk is two in one thousand (2×10^{-3}) for a lifetime exposure to contaminants in water from a potential monitor well drilled 250 feet west of LLNL. The HI calculated for this scenario is 1. Because no drinking water wells are likely to be drilled in the area 250 feet west of LLNL, we also calculated the risk based on a lifetime exposure to well water derived from downtown Livermore using the health conservative assumptions. This unlikely scenario results in a maximum additional cancer risk of one in one thousand (1×10^{-3}) and an HI of 1. The HI of 1 for the health-conservative scenario indicates that there is some potential for noncarcinogenic health effects if the very conservative assumptions of the health conservative scenario were ever realized, and if there was an additive effect of all the individual compounds. Both health-conservative risks in Table 4 exceed EPA's one in ten thousand to one in ten million (1×10^{-4} to 1×10^{-7}) acceptable risk range for Superfund sites.

2.6.1.4.4. Sources of Uncertainty

Uncertainties are associated with all estimates of cancer and noncancer health hazards. These uncertainties result from incomplete knowledge of many physical and biological processes, such as carcinogenesis. Where specific information is not available, it is necessary to make assumptions and/or use predictive models to compensate for lack of information. The

assumptions, models, and calculations are chosen such that the resulting risk and hazard estimates are health-conservative. The specific sources of uncertainty in the risk and hazard estimates presented here are further discussed in the BPHA.

2.6.1.5. Environmental Risks

Currently, there is no potential risk of ecological impacts related to environmental exposure to ground water because no ground water containing contaminants is present at the surface, either onsite or offsite. No perennial streams exist at or near the site and no streams receive flow from ground water. No critical habitats are affected by the ground water and soil contamination. No endangered species or habitats of endangered species are affected by the site contaminants, as described in the FS (Isherwood *et al.*, 1990).

2.6.1.6. Risk Assessment Conclusions

In summary, the identified compounds of concern, if not addressed by implementing the response actions selected in this ROD, may present a potential risk to public health.

2.7. Description of Remedial Alternatives

In the FS, three remedial alternatives were assembled for ground water for the LLNL site:

1. *Ground water extraction throughout the contaminated area, including source areas, thereby preventing further contaminant migration and enabling the most rapid cleanup.* Ground water would be treated at the surface using UV/oxidation or air stripping-based technology with GAC to prevent any measureable air emissions. The treated water would be recharged or used at the LLNL site.
2. *Ground water extraction at the downgradient edges of contamination to prevent further contaminant migration.* Ground water would be treated at the surface, as for Alternative No. 1, and recharged or used at the LLNL site.
3. *Ground water monitoring and treatment at the point of use, if drinking water supply wells should ever contain contaminants from LLNL in concentrations above drinking water standards.* Ground water would be treated at the surface as described in No. 1 above.

The remedial alternatives for contaminants in the unsaturated sediment were:

1. *Vacuum-induced venting with surface treatment of vapors using GAC, thermal oxidation, or catalytic oxidation.*
2. *Deferring action to see if contaminants migrate to the ground water, and, if they do, extracting and treating the ground water as described for the ground water remedial alternatives.*

A third alternative, excavation and treatment and/or disposal, was also considered for unsaturated sediment. However, this alternative would be applicable only if (1) contaminant concentrations are found in the unsaturated zone that are high enough to cause concentrations above MCLs in the ground water, and (2) they occur at relatively shallow, accessible depths. Currently, no known locations meet these criteria, and this alternative was not considered further. However, excavation, treatment, and/or disposal could be employed in the future if high concentrations of contaminants, treatable perhaps by bioremediation or aeration, are discovered at excavatable depths.

The volume of ground water that contains contaminants above MCLs is much greater than the volume of unsaturated sediment containing contaminants that may impact the ground water in concentrations above MCLs.

The ground water and unsaturated sediment alternatives were developed by considering the nine evaluation criteria prescribed by EPA, as discussed in the FS. The FS discusses the various technologies for treating extracted ground water and vapor and assembles them into treatment options. The preferred treatment options vary from place to place because different parts of the site contain somewhat different combinations of contaminants in ground water and unsaturated sediment.

All the remedial alternatives considered for the LLNL site would include long-term ground water monitoring and reporting, in compliance with CERCLA requirements, until demonstrated achievement of the remedial action objectives. The costs of these activities, which are common to all alternatives for their respective estimated times of operation, were not explicitly addressed in the FS, but were presented in the PRAP to reflect the additional costs of maintaining a remediation program into the distant future. Monitoring activities will be conducted and reviewed periodically to gauge the effectiveness of the remedies. For all alternatives, the costs and implementation times were estimated using the assumptions discussed in the FS. The program operations costs, which were not described in the FS, are summarized in Appendix A of the PRAP (Dresen *et al.*, 1991).

All the treatment options for ground water will reduce the effluent concentration of VOCs, FHCs, chromium, and lead below Applicable or Relevant and Appropriate Requirements (ARARs) (Isherwood *et al.*, 1990). Tables 3-1 and 3-2 in the FS, and Table 1 and Appendix B of this ROD summarize the ARARs for the LLNL site.

As discussed in Section 2.8, Ground Water Alternative No. 1 and Unsaturated Zone Alternative No. 1 meet all ARARs. Ground Water Alternatives 2 and 3 and Unsaturated Zone Alternative 2 do not fully comply with the California non-degradation ARAR.

For treatment options that include disposal of treated ground water or air emissions, the effluent concentrations will be in compliance with RWQCB Waste Discharge Requirements, National Pollutant Discharge Elimination System (NPDES), and BAAQMD standards. Treated ground water will be recharged at the LLNL recharge basin south of East Avenue, in local drainage ditches and arroyos, or in infiltration trenches or recharge wells. Treated water will also be used for onsite landscape irrigation and in LLNL's cooling towers.

The approach for tritium is to keep it in the subsurface as much as possible where it will decay naturally (i.e., self-remediate) and to minimize its migration. Extraction systems will be designed and operated to prevent tritium from entering a treatment system in concentrations above its MCL. This will be accomplished by monitoring the influent water to the treatment system, both in pipelines and in the well(s). If water containing tritium above the MCL enters a treatment system, the facility will be shut down, and the water containing tritium will be treated by evaporation under existing National Environmental Standards for Hazardous Air Pollutants requirements, or released within allowable limits under the existing permit to the sanitary sewer system. No treated ground water will be recharged back to the subsurface if the tritium level exceeds the MCL.

Treatment options utilizing air stripping will be designed with GAC on the effluent air stream, so there are no measurable VOC air emissions. For those options employing GAC to treat water or air streams, the GAC will be shipped offsite where it will be commercially regenerated to destroy or recycle, if possible, the adsorbed contaminants. Options employing ion exchange for treatment of metals will require offsite recycling or disposal of the ion-exchange resin as a hazardous waste. The expected risk reduction after cleanup is complete is described in Section 2.9.1 of this ROD.

2.7.1. No-Action Alternative

A No-Action Alternative was considered in the FS for the LLNL site to establish a baseline for comparison. Under this alternative, LLNL would cease all characterization and remedial

activities. Limited ground water monitoring would continue to track changes in ground water chemistry. The No-Action Alternative is not the same as the Deferred-Action Alternatives discussed in the FS and the PRAP, in that remedial actions may be taken in the future under the Deferred-Action Alternatives. The No-Action Alternatives for ground water and unsaturated sediment do not meet Federal and State standards to protect human health and were not considered viable in the FS and the PRAP.

2.7.2. Ground Water Remedial Alternatives

Two ground water extraction plans that use different arrays of extraction wells form the basis for immediate-action alternatives to remediate ground water. Each extraction plan is discussed subsequently with its remedial alternative.

Costs for the ground water remedial alternatives are summarized in Table 5. In the FS, costs were analyzed using a present worth calculation procedure, as prescribed by EPA. This is the standard procedure for comparing alternatives with costs and revenues beginning, ending, or extending over different periods of time.

2.7.2.1. Ground Water Remedial Alternative No. 1 (The Selected Alternative)

2.7.2.1.1. Ground Water Extraction Plan for Remedial Alternative No. 1—Complete Capture and Source Area Extraction

Under this plan, extraction wells would be strategically placed near contaminant margins to intercept and hydraulically control all ground water originating from LLNL with VOC concentrations exceeding MCLs. In addition, ground water would be extracted from source areas (defined here as those areas with concentrations above about 100 ppb in ground water) to expedite cleanup. This plan would utilize 18 initial extraction locations and about 7 treatment facilities shown conceptually on Figure 7. A plot of the predicted ground water flow patterns using these locations is shown in Figure 8. The flow lines (with arrows on Fig. 8) converge on extraction locations and show the areas hydraulically captured by the extraction wells. The total rate of ground water removal for this extraction plan is estimated to be about 350 gallons per minute (gpm). Where VOCs and tritium occur together in ground water, the extraction systems will be designed and monitored to minimize tritium migration and to prevent the water influent to any treatment systems from containing tritium in concentrations above the MCL. Therefore, no tritium will be released from treatment systems in concentrations above the MCL.

The 350-gpm sitewide extraction rate is a preliminary estimate used to estimate capture areas, cleanup times and costs relative to other alternatives presented in the PRAP and ROD. This extraction rate and the estimated treatment facility capacities will be analyzed and further refined in the Remedial Design and as part of ongoing work to decrease cleanup times and optimize extraction and recharge rates.

It is estimated that it would take about 50 years to reduce contaminant concentrations to MCLs if only the 18 initial extraction locations are employed. LLNL plans to implement the selected cleanup plan in phases, and evaluate each phase with field data. Additional extraction locations may be used to ensure full hydraulic capture of the plume, and/or to expedite cleanup. If technologically feasible, and if funding permits, LLNL will attempt to achieve cleanup in less than the predicted 50 years. It is estimated that all extraction and treatment facilities under Alternative 1 would be operational in the 1993-94 timeframe, depending on congressional funding. LLNL will make every effort to obtain sufficient funding to fully support the selected cleanup plan. This alternative will comply with all ARARs.

Table 5. Summary of costs for ground water remedial alternatives for the LLNL Livermore site.

Remedial alternative	Present worth costs (millions of 1990 dollars) ^a			
	Capital costs ^b	Treatment system O&M costs ^c	Program operations ^d	Total present worth of alternative ^e
Remedial Alternative No. 1 50-year operation—UV/oxidation primary treatment at Treatment Facilities A, B, E, and F; air stripping primary treatment at Treatment Facilities C, D, and G	9	21	73	103
Remedial Alternative No. 2 90-year operation—UV/oxidation primary treatment at Treatment Facilities A, B, and F; air stripping primary treatment at Treatment Facility C	6	14	79	99
Remedial Alternative No. 3a ^f 30-year operation beginning in 200 years; air stripping treatment at the point of distribution in Livermore	0.01	0.03	87	87
Remedial Alternative No. 3b ^g Monitoring 10 wells for 100 years	0.00	0.00	12	12

^a Present worth calculated using a 5% discount rate for Remedial Alternative No. 1 over 50 years and Remedial Alternative No. 2 over 90 years; and, for Remedial Alternative No. 3, a 5% rate for a 30-year operation and then at a 2% rate for 200 years from possible commencement of treatment to 1990 for operation and maintenance, and 230 years for program operations.

^b Total capital costs of treatment systems, extraction wells, pipelines, water recharge and reuse facilities, monitor wells, and piezometers.

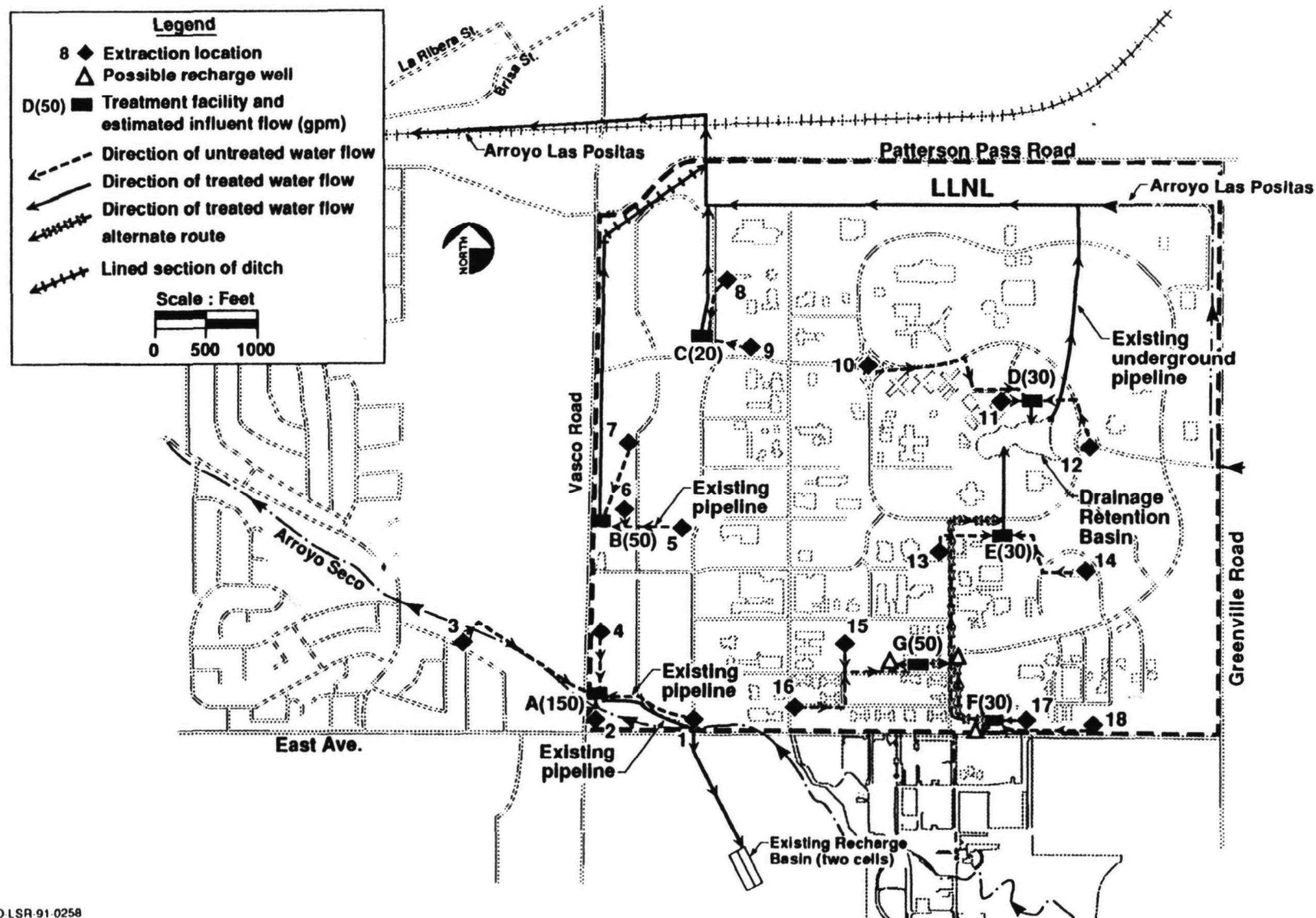
^c Present worth of annual operating and maintenance costs of treatment systems, extraction wells, pipelines, water recharge and reuse facilities, monitor wells, and piezometers.

^d Present worth of annual program operations; see Appendix A of PRAP (Dresen *et al.*, 1991) for details.

^e Sum of present worths of capital costs, treatment systems, operating and maintenance, and program operations.

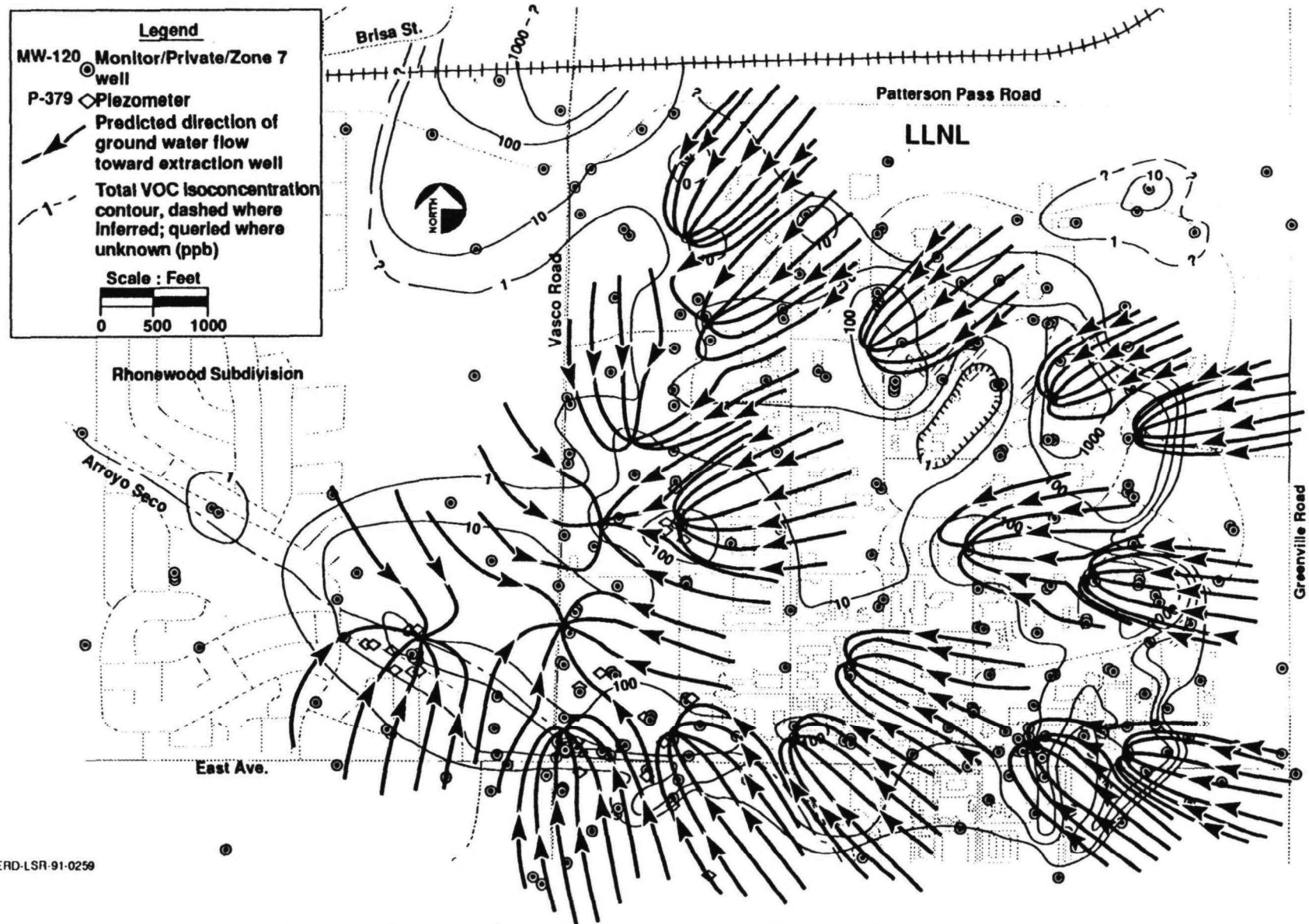
^f Cost estimate for this alternative assumes that VOCs might migrate to Livermore municipal-supply wells in 200 years, if ever. Program operations costs are assumed to be \$1.75 million per year.

^g Assumes lower program operations costs, \$0.6 million per year, monitoring of 10 wells for 100 years, and no treatment because computer modeling predicts that VOCs in ground water may never exceed MCLs in Livermore municipal-supply wells.



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Figure 7. Preliminary ground water extraction and treatment facility locations.



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Figure 8. Predicted ground water flow pathways for Extraction Alternative No. 1—Complete Capture and Source Remediation.

2.7.2.1.2. Treatment Options for Ground Water Remedial Alternative No. 1

Ground Water Containing VOCs (Proposed Treatment Facilities A, B, C, E, and G) (Fig. 7). Treatment Facility E could potentially receive ground water containing tritium as well as VOCs.

Treatment Option 1. Granular-Activated Carbon. (GAC) Ground water pumped by extraction wells would pass through beds of activated carbon where VOCs would be removed by GAC. The operating costs of this treatment option are high.

Treatment Option 2. Air Stripping with GAC Treatment of the Vapor. Ground water pumped by extraction wells would pass through an air stripper where VOCs would be removed by transferring them from the water to the air. The vapors from the stripper would pass through GAC to completely remove contaminants. This treatment option is the most economical for ground water containing VOCs.

Treatment Option 3. UV/Oxidation Plus Air Stripping with GAC Filtering of the Vapor. Extracted ground water would be blended with small amounts of hydrogen peroxide and exposed to strong ultraviolet (UV) light, destroying most of the contaminants. LLNL pilot studies have shown that some compounds require secondary treatment by air stripping, which would be added to treat water after it passed through the UV/oxidation unit. The vapors from air stripping would pass through GAC to remove contaminants. This option reduces the amount of waste requiring further treatment or disposal, especially where the majority of the contaminants are readily oxidized by the UV/oxidation process. Costs for this option are moderately high.

Treatment Option 2 or 3 is preferred for Treatment Facilities A, B, C, E, and G, depending on the concentrations and types of the compounds, and the flow rate influent to each treatment facility.

Ground Water Containing VOCs and Chromium (Proposed Treatment Facility D) (Fig. 7)

Treatment Option 1. GAC Plus Ion Exchange. Ground water pumped by extraction wells would pass through GAC beds, which would remove the VOCs. The VOC-free water would then be fed through an ion-exchange resin to extract chromium. The operating costs of this treatment option are high.

Treatment Option 2. Air Stripping with GAC Filtering of the Vapor Phase Plus Ion Exchange. Extracted ground water would pass through an air stripper to remove VOCs. The vapors from the stripper would pass through GAC to remove VOCs from the air. The VOC-free water would flow through an ion-exchange resin to extract chromium. This treatment option is preferred because the higher concentrations of TCE, carbon tetrachloride, chloroform, and Freon 113 make this treatment option more economical.

Treatment Option 3. UV/Oxidation Plus Air Stripping and Ion Exchange with GAC Treatment of the Vapor. Extracted ground water would be treated by UV/oxidation, destroying most of the VOCs. Remaining VOCs would be removed from the water by air stripping. The vapors from the air stripper would pass through GAC to completely remove VOCs. The VOC-free water would then flow through an ion-exchange resin to extract chromium. The operating costs of this treatment option are high.

Ground Water Containing FHCs, VOCs, and Lead (Proposed Treatment Facility F) (Fig. 7)

Treatment Option 1. GAC Treatment. Ground water pumped by extraction wells would pass through GAC beds, which remove the FHCs, VOCs, and lead. The operating costs of this treatment option are high.

Treatment Option 2. Air Stripping with GAC Treatment of Both the Vapor and Liquid Phases. Extracted ground water would pass through an air stripper to remove FHCs and VOCs. The vapors from the stripper would pass through GAC to completely remove FHCs and VOCs.

The water would then pass through GAC to extract lead and any remaining FHCs or VOCs. This treatment option is not preferred because the high concentration of FHCs would require frequent carbon regeneration that increases the operating costs of this treatment option substantially.

Treatment Option 3. UV/Oxidation Plus GAC. Extracted ground water would be treated by UV/oxidation, destroying most contaminants. The water would then pass through GAC beds to remove lead and any remaining FHCs or VOCs. This treatment technology is preferred because it can handle the high concentrations of FHCs. It is also the most economical of the treatment options.

Treatment Option 4. Subsurface Bioremediation. Biological treatment would utilize the metabolic destruction of organic compounds by microbes that convert the organic compounds in the ground water to less toxic compounds. Bioremediation of the FHCs in the Gasoline Spill Area is potentially viable. However, the relatively great depth of FHCs at LLNL, which makes providing the correct physical and chemical conditions for the microbes difficult, and the sensitivity of microorganisms to subsurface conditions that are difficult to control, make applicability of subsurface bioremediation at LLNL uncertain. In addition, bioremediation has not yet been proven successful for chlorinated VOCs. Therefore, this treatment option was not considered as an initial remedial action.

2.7.2.2. Ground Water Remedial Alternative No. 2

2.7.2.2.1. Ground Water Extraction Plan for Remedial Alternative No. 2—Downgradient Control

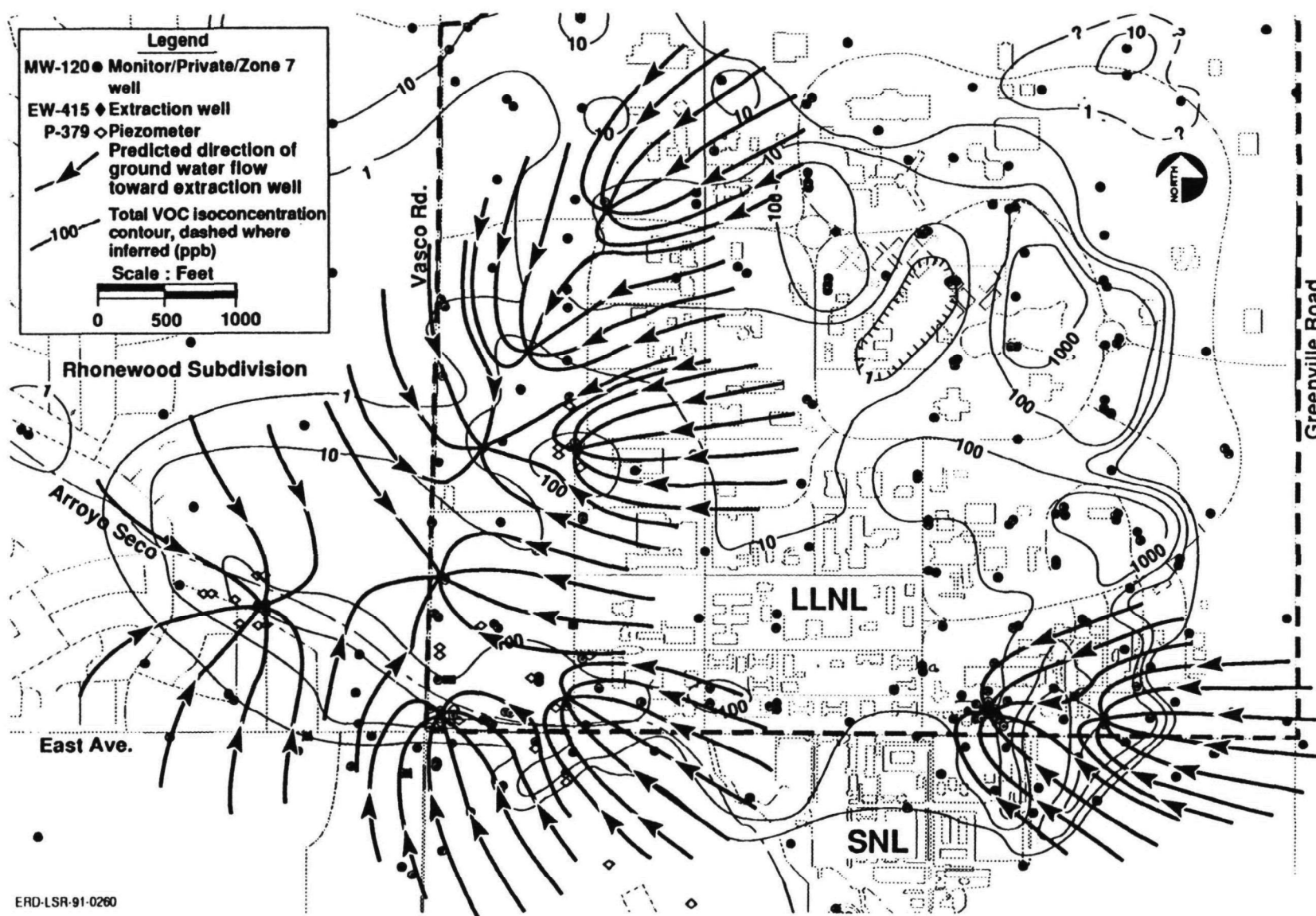
Under this plan, extraction wells would be placed along the western boundary of LLNL to intercept and hydraulically control the offsite migration of those VOCs in concentrations exceeding MCLs. In addition, extraction would also occur in the Gasoline Spill Area, where a pilot remediation study is ongoing, and in the adjacent Building 518 Area to prevent migration of FHCs and VOCs to the south of LLNL. This plan would use a total of 10 extraction locations, 1 through 7 and location 9 in and near the western boundary of LLNL and locations 17 and 18 in the southeastern part of LLNL (Fig. 7). Extracted water would be treated at Treatment Facilities A, B, C, and F (Fig. 7). A plot of the predicted ground water flow patterns using the extraction locations for this plan is shown in Figure 9. The rate of ground water extraction for this plan is estimated to be about 200 gpm. This alternative would contain and remediate all known contaminants. It is estimated that it would take more than 90 years to achieve MCLs under this plan and that all extraction and treatment facilities would be operational in 1993.

2.7.2.2.2. Treatment Options for Ground Water Remedial Alternative No. 2

This alternative differs from Alternative No. 1 in that fewer initial extraction locations (10 compared to 18 for Alternative No. 1) and treatment facilities (4 compared to 7 for Alternative No. 1) would be employed. The treatment options discussed in Section 2.7.2.1.2 for Treatment Facilities A, B, C, and F would be identical for this alternative.

2.7.2.3. Ground Water Remedial Alternative No. 3—Deferred Action

For the Deferred-Action Remedial Alternative, ground water would not be treated until *and unless* contaminants in concentrations greater than MCLs migrate to a drinking water supply well, such as those operated by the California Water Service Company, located about 2 miles west of LLNL. Under this alternative, treatment would take place at the point of distribution for the affected water-supply system. If contaminants did reach supply wells, probably no sooner than about 200 years, their concentrations would be substantially lower than those currently at LLNL (Thorpe *et al.*, 1990). The ground water would be treated, at a minimum, to conform to the MCLs for each contaminant before it is distributed for human consumption. Selection of an appropriate treatment option would be made at the time that treatment may be necessary because



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Figure 9. Predicted ground water flow pathways for Extraction Alternative No. 2—Downgradient Control.

technology and economics may have changed considerably by then. Currently available options are presented below for comparison.

2.7.2.3.1. Treatment Options for Ground Water Remedial Alternative No. 3

Treatment Option 1. GAC Treatment. Ground water pumped by water-supply wells would pass through GAC beds to remove contaminants.

Treatment Option 2. Air Stripping. Ground water pumped by water-supply wells would pass through an air stripper. Because only very low concentrations of VOCs may ever occur in water from supply wells (Thorpe *et al.*, 1990), treatment of air emissions would most likely be unnecessary. This treatment option is preferred because concentrations of compounds will be very low and it is the most economical of the treatment options.

Treatment Option 3. UV/Oxidation. Ground water pumped by water-supply wells would be treated by UV/oxidation. The concentrations of VOCs are expected to be reduced sufficiently so that secondary treatment would be unnecessary.

2.7.2.4. Comparison of Ground Water Treatment Option Costs

For each extraction and treatment alternative described above, several treatment technology options passed initial screening and were subjected to a detailed evaluation in Section 4 of the FS. For purposes of comparing the treatment technologies in the FS, cost estimates were prepared (see Appendices D, E, and F of the FS) using U.S. EPA's suggested 30 years operating and maintenance period (U.S. EPA, 1989b). A supplemental analysis was conducted for several of the treatment facilities assuming 90 years of operation would be required for Alternative No. 2 to achieve ARARs. This detailed analysis indicates that, in general, for the same length of operation (e.g., 30 years), (1) GAC is about 1.8 times more expensive in present worth for a treatment facility than air stripping and (2) UV/oxidation treatment is 1.3 times as expensive in present worth as air stripping. Alternative No. 3 has a very low present worth, ranging from \$30,000 for air stripping to \$280,000 for GAC, largely because the long timespan prior to possible commencement of treatment reduces the total costs of this alternative in the discounting procedure. This also takes into account the different combinations of contaminants and treatment options at each treatment facility.

In summary, GAC is generally the most costly treatment technology, followed by UV/oxidation, and then by air stripping. However, the costs in the FS do not include the program operations costs in Appendix A of the PRAP. These costs do not significantly affect the relative costs of the treatment options, but they are significant in magnitude when comparing remedial alternatives with different periods of operation.

2.7.3. Unsaturated Zone Alternatives

Costs of remedial alternatives for the unsaturated zone are summarized in Table 6. The remedial alternatives and treatment options are described below.

2.7.3.1. Unsaturated Zone Remedial Alternative No. 1—Vacuum-Induced Venting (the Selected Alternative)

Current data indicate that only FHCs in the Gasoline Spill Area, VOCs in the Building 518 Area in the southeastern part of the LLNL site, and possibly VOCs in the vicinity of the Trailer 5475/East Taxi Strip Area in eastern LLNL will need unsaturated zone remediation (Isherwood *et al.*, 1990). FHCs and/or VOCs would be removed from the subsurface by vacuum-induced

Table 6. Summary of costs for unsaturated zone remedial alternatives for the LLNL Livermore site.

Remedial alternative	Present worth costs (thousands of 1990 dollars) ^a			Total present worth of alternative
	Capital costs ^b	Treatment system O&M costs ^c	Program operations ^d	
Remedial Alternative No. 1 Immediate action—10-year operation; vapor withdrawal and catalytic oxidation treatment; vapor from Building 518 piped to Treatment Facility F ^e	529	585	0	1,114
Remedial Alternative No. 2 Deferred action ^f —monitor and extract and treat ground water, if necessary	0	252 ^g	600 ^h	852

^a Present worth calculated using a 5% discount rate for Remedial Alternative No. 1 over 10 years; and, for Remedial Alternative No. 2, a 5% rate for 50 years from possible commencement of treatment in 1990, and a 5% rate for 40 years of operation.

^b Total capital costs of treatment systems, extraction wells, and monitor wells.

^c Present worth of annual operating and maintenance costs of treatment systems, extraction wells, and monitor wells.

^d Included with ground water remediation only because the major remediation is associated with ground water.

^e The present worth of extracting and piping vapor from the Building 518 Area to Treatment Facility F is \$175,000 for 5 years of operation (including O&M) necessary to achieve ARARs. The present worth of installing a separate catalytic oxidation unit at the Building 518 Area and operating it for 5 years is \$1,100,000 (including O&M).

^f Assumes a 50-to 60-year period before VOCs and/or FHCs migrate to ground water from the unsaturated zone in concentrations above MCLs. Treatment by UV/oxidation at Treatment Facility F for 40 years beginning in 50 years (equivalent to the difference between Remedial Alternatives No. 1 and 2 at Treatment Facility F).

^g Does not include costs of additional monitoring, extraction, or recharge wells or piezometers that may be necessary.

^h Ten percent of program operations costs charged to this alternative from years 51 through 90 because they would not otherwise be necessary ($4,000,000 \times 0.1 \times 1.5$ discount factor present worth of annual expenses from years 51 to 90).

venting using extraction wells. Treatment options for the extracted vapor are described in the following section. If vapor extraction were ever considered for any of the localized areas at LLNL where elevated levels of tritium occur in the unsaturated zone, the water portion of the vapor could be (1) released to the atmosphere or (2) separated from the vapor by condensation. For possible tritium air releases from treatment systems, the AIRDOS-EPA computer model would be used to evaluate the potential annual dose to a hypothetical maximally exposed individual. LLNL will shut down any treatment system that emits tritium to the atmosphere at a rate predicted to contribute to an exposure of greater than 10 millirem/year (the Federal standard for clean air).

We estimate that it would take about 10 years to remediate the unsaturated zone under this alternative and that remediation would be underway by late 1992.

Treatment Options for Unsaturated Zone Remedial Alternative No. 1

Treatment Option 1. GAC Treatment. Vapors from vent wells would pass through a chamber containing GAC to remove VOCs or FHCs. The treated vapor would be discharged to the atmosphere.

Treatment Option 2. Thermal Oxidation. Vapors from vent wells would pass through a thermal oxidation chamber where the FHC and VOC vapors would be oxidized with the assistance of a heat source such as propane. The VOCs and FHCs would be destroyed and treated air would be discharged to the atmosphere.

Treatment Option 3. Catalytic Oxidation. Vapors from vent wells would be heated and passed through a catalyst, where organic compounds would be converted to harmless oxidation products, such as carbon dioxide and water. The treated air would be discharged to the atmosphere. A catalyst suitable for both VOCs and FHCs has recently been found. The rationale for preferring catalytic oxidation over thermal oxidation for treatment of vapors is presented in Appendix B of the PRAP. If use of catalytic oxidation results in emission of vapors with compounds above regulatory standards, secondary treatment or alternative technologies, such as GAC, will be evaluated and implemented to comply with regulatory standards.

2.7.3.2. Unsaturated Zone Remedial Alternative No. 2—Deferred Action

Under this alternative, all contaminants in the unsaturated zone would be left in place and allowed to degrade, volatilize, or migrate to ground water under natural conditions. Ground water would continue to be monitored according to the requirements of CERCLA. If any contamination of ground water above MCLs occurs, it would either be remediated by ongoing ground water extraction and treatment, or by additional ground water extraction and treatment systems, if necessary.

2.7.3.3. Comparison of Unsaturated Zone Treatment Option Costs

The relative present worth costs for the three vadose zone treatment options are discussed in Section 4 of the FS. In summary, the present value of GAC is about 50% greater than for thermal oxidation, and catalytic oxidation is about 20% less than thermal oxidation.

2.8. Summary of the Comparative Analysis of Alternatives

The remedial alternatives and associated treatment options were evaluated against nine EPA criteria in the FS and PRAP. The preferred remedial alternatives for ground water and unsaturated sediment were analyzed in terms of these nine criteria and are summarized in Tables 7 and 8.

Table 7. Comparison of ground water remedial alternatives for the LLNL Livermore site.^a

Remedial alternative/ treatment technologies	Protective of human health and the environment	Compliance with ARARs	Long-term effectiveness
Remedial Alternative No. 1^b UV/oxidation-based systems for Treatment Facilities A, B, E, and F. Air stripping-based systems for Treatment Facilities C, D (plus ion exchange), and G.	Risk is reduced by design criteria that are lower than ARARs. Reduces ground water contaminant concentrations to MCLs; design criteria for treated ground water are lower than discharge limits.	Meets all ARARs.	Effective.
Remedial Alternative No. 2 UV/oxidation-based systems for Treatment Facilities A, B, and F. Air stripping-based system for Treatment Facility C.	Risk is reduced by design criteria that are lower than ARARs. Reduces ground water contaminant concentrations to MCLs; design criteria for treated ground water are lower than discharge limits.	Does not fully satisfy the State of California ARAR concerning non-degradation of water resources.	Effective.
Remedial Alternative No. 3 Deferred treatment— Air stripping at point of distribution, if necessary.	Risk reduced by treatment at point-of-distribution (if necessary). Ground water quality would be degraded until treatment begins or concentrations naturally fall below MCLs.	Does not fully satisfy the State of California ARAR concerning non-degradation of water resources.	Effective.

^a Using the nine EPA criteria for detailed evaluation of alternatives (U.S. EPA, 1988a, pp. 6-1 to 6-31).

^b The selected alternative.

^c Present worth is calculated to reflect the time value of money in excess of inflation, as described in Section 5.2 of the PRAP (Dresen *et al.*, 1991).

^d If monitoring of ground water only were to be conducted for 100 years, the present worth cost would be \$12 million.

UV = Ultraviolet light.

Reduce toxicity, mobility, and volume or mass	Short-term effectiveness	Implementability (technical and administrative)	Present worth cost ^c	State acceptance	Community acceptance
Reduces mobility by downgradient hydraulic containment and source area extraction. Toxicity/mass reduced by extraction and surface treatment.	Negligible impacts during installation and operation. About 50 years required to achieve MCLs in ground water.	Implementable.	\$103 million	Acceptable	The community accepts the concept of the selected alternative, but desires funding commitments, a detailed implementation schedule, continued opportunity for involvement, and a faster cleanup.
Reduces mobility through downgradient hydraulic containment; allows migration of contaminants across LLNL site. Toxicity/mass reduced by extraction and surface treatment.	Negligible impacts during installation and operation. Ninety or more years required to achieve MCLs in ground water.	Implementable.	\$99 million	Not acceptable	The community accepts the concept of a pump and treat alternative, but prefers Alternative No. 1 because it is more expedient and employs active source remediation.
Reduces volume by natural degradation rather than by treatment. Allows migration of contaminants beyond present extent, and increase in the volume of contaminated water.	Remediation deferred until or unless VOCs impact in-use water supplies. Negligible impacts during installation and operation. Estimated 360 years for natural degradation to reduce contaminant concentrations below MCLs, and 30 years to achieve MCLs after treatment commences in 200 years, if necessary.	Implementable. Alternative may not be acceptable to regulatory agencies because it delays remediation an estimated 200 years.	\$87 million ^d	Not acceptable	Not acceptable

Table 8. Comparison of unsaturated zone remedial alternatives for the LLNL Livermore site.^a

Remedial alternative	Protective of human health and the environment	Comply with ARARs	Long-term effectiveness
Remedial Alternative No. 1^c			
Immediate Action			
Vacuum extraction and catalytic oxidation.	Risk reduced by actively removing contaminants from the unsaturated zone.	Meets all ARARs.	Effective.
Remedial Alternative No. 2			
Deferred Action			
Remove contaminants that have migrated to ground water by extraction and treatment at the nearest treatment facility.	Risk to humans not actively reduced until VOCs or FHCs migrate to ground water. Ground water quality would be degraded until treatment begins or natural processes reduce concentrations below MCLs.	Does not fully satisfy a State of California ARAR concerning non-degradation of water resources where migration to ground water will result in concentrations greater than MCLs.	Effective.

^a Using the nine EPA criteria for detailed evaluation of alternatives (U.S. EPA, 1988a, pp. 6-1 to 6-31).^b Present worth is calculated to reflect the time value of money in excess of inflation, as described in Section 5.2 of the PRAP (Dresen *et al.*, 1991).^c The selected alternative.

Reduce toxicity, mobility, and volume or mass	Short-term effectiveness	Implementability (technical and administrative)	Present worth cost ^b	State acceptance	Community acceptance
Reduces mobility by actively removing VOCs from the subsurface. Reduces toxicity/mass by extraction and treatment at the surface.	Negligible impacts during installation and operation. About 10 years required to achieve remedial action objectives.	Implementable.	\$1.1 million	Acceptable	The community accepts the concept of the selected alternative, but desires funding commitments, a detailed implementation schedule, continued opportunity for involvement, and a faster cleanup.
Does not reduce contaminant mobility in the unsaturated zone. Volume reduced by natural degradation rather than by treatment in an estimated 90 years.	Effective for both VOCs and FHCs; as much as 90 years required to achieve remedial action objectives.	Implementable.	\$0.9 million	Not acceptable	The community appears to accept the concept of this alternative, but prefers Alternative No. 1.

2.8.1. Ground Water

Overall Protection of Human Health and the Environment. All the ground water remedial alternatives are equally protective of human health (if institutional controls are in effect for Alternative 3 to prevent new or existing wells from being used) because each is designed to meet the same cleanup criteria. Consequently, the resulting health risks are identical among the alternatives (Isherwood *et al.*, 1990). Since Alternatives 2 and 3 would allow some continued migration of VOCs in ground water, they also allow some degradation of the subsurface environment.

Compliance with ARARs. Ground water Remedial Alternatives No. 1 and No. 2 are designed to achieve all ARARs (Isherwood *et al.*, 1990). However, Alternative No. 2 would allow higher-concentration VOCs in eastern LLNL to migrate across the site, and thus does not fully satisfy the State of California ARAR regarding non-degradation of water resources. Remedial Alternative No. 3, treat at point-of-use, though estimated to be protective of human health (Isherwood *et al.*, 1990), does not fully satisfy the California non-degradation ARAR.

Long-Term Effectiveness and Permanence. All three remedial alternatives are equally effective in terms of permanence and stability of remediation and reduction in health risks by removing and treating the contaminants.

Reduction in Toxicity, Mobility, and Volume. Remedial Alternatives No. 1 and No. 2 reduce toxicity, mobility, and volume of the compounds. Alternative No. 1 does not allow additional contaminant migration beyond the current extent downgradient. Alternative No. 2 allows VOCs in eastern LLNL to migrate across the site. Remedial Alternative No. 3, deferred action, allows more contaminant mobility than Alternative No. 2 and does not reduce contaminant mobility until and unless contaminants reach domestic or municipal wells in concentrations above an MCL.

An advantage of the UV/oxidation remediation technology (preferred at Treatment Facilities A, B, E, and F) is that TCE, PCE, 1,1-DCE, and FHCs are destroyed in one process, thereby minimizing waste requiring further treatment or disposal. Use of GAC requires regeneration of spent carbon to convert the captured compounds to harmless substances. Ion-exchange resins for metals removal may require disposal as hazardous waste.

Short-Term Effectiveness. All the remedial alternatives would expose workers, the public, and the environment to negligible impacts during installation and operation.

The selected remedial alternative is estimated to achieve the remediation goals in about 50 years compared to 90 years or more for Remedial Alternative No. 2, which employs only four treatment facilities and ten extraction locations. Alternative No. 3 may take about 230 years to achieve remediation goals, and remediation may not begin for 200 years. Each treatment option, combined with the same remedial alternative, would require about the same length of time to achieve the remediation goals. For Alternative No. 1, it is estimated that plume containment and overall hydraulic control will be achieved in 1995. This estimate will be further refined in the Remedial Design.

Implementability. Each of the remedial alternatives and technology options is technically and administratively feasible and supported by available services, materials, and skilled labor. An advantage of the UV/oxidation technology over the GAC technology is that regeneration of the spent carbon is unnecessary. The air-stripping-based and UV/oxidation-based technologies generate substantially less spent carbon than the GAC system for water treatment. UV/oxidation and GAC technologies also have minimal visual impact compared to air-stripping towers.

Cost. The present worth of Ground Water Remedial Alternative No. 1 (the selected alternative) is estimated to be \$103 million, assuming 50 years of operation. The present worth for 90 years of operation for Remedial Alternative No. 2 is \$99 million. The present worth for Remedial Alternative No. 3 is \$87 million, assuming air stripping is the treatment option used. If Remedial Alternative No. 3 consisted only of monitoring ground water for 100 years, the present worth would be \$12 million.

State Acceptance. The California RWQCB and DTSC accept the selected ground water remedial alternative, Remedial Alternative No. 1. The RWQCB does not accept Ground Water Alternatives No. 2 and No. 3 since they do not fully satisfy the California non-degradation ARAR.

Community Acceptance. The community accepts the general concept of the selected alternative, but desires funding commitments, a detailed implementation schedule, continued opportunity for involvement, and a faster cleanup. Implementation schedules will be included in post-ROD documents called the Remedial Action Implementation Plan and the Remedial Design/Remedial Action reports. LLNL is continually exploring and implementing new methods and techniques that will accomplish the fastest cleanup.

2.8.2. Unsaturated Zone

The remedial alternatives for the unsaturated zone are described below and compared in Table 8 in terms of the EPA evaluation criteria.

Overall Protection of Human Health and the Environment. Unsaturated Zone Remedial Alternative No. 1 is protective of human health and the environment and creates minimal health risks. Remedial Alternative No. 2 has some impact on the subsurface above the water table as contaminants would be allowed to migrate naturally. Estimates indicate natural processes would reduce the concentrations to below MCLs in 90 to 140 years (Isherwood *et al.*, 1990, Appendix G).

Compliance with ARARs. Remedial Alternative No. 1 is designed to achieve ARARs. Alternative No. 2 may allow contaminants to reach the ground water in concentrations exceeding MCLs in a few isolated places (i.e., the Gasoline Spill and Building 518 Areas, and perhaps the East Taxi Strip Area), and therefore does not meet the California non-degradation ARAR.

Long-Term Effectiveness and Permanence. Both of the alternatives are effective in the long run and reduce health risks permanently by removing and treating contaminants.

Reduction in Toxicity, Mobility, and Volume. Remedial Alternative No. 1 results in the immediate removal and complete breakdown of compounds to harmless substances, thereby permanently reducing toxicity, mobility, and volume. Remedial Alternative No. 2 (deferred action) allows VOCs and FHCs to continue to migrate through the unsaturated zone to the ground water. VOCs and FHCs would then be extracted and treated in the ground water at the nearest treatment facility.

Short-Term Effectiveness. Both alternatives would expose workers, the public, and the environment to negligible impacts during installation and operation. Achieving the remediation objectives is estimated to require 10 years for the selected alternative, Alternative No. 1, and 90 years for Alternative No. 2.

Implementability. Both alternatives are technically and administratively feasible and supported by available services, materials, and skilled labor.

Cost. Present worth cost for 10 years of operation for the preferred alternative is \$1.1 million. The preferred alternative utilizes the most cost effective treatment option available for both VOCs and FHCs. The present worth of Alternative No. 2 is \$850,000.

State Acceptance. The California RWQCB and DTSC accept the selected unsaturated zone alternative, Remedial Alternative No. 1. The RWQCB does not accept Unsaturated Zone Alternative No. 2 since it may allow ground water degradation.

Community Acceptance. The community accepts the general concept of the selected unsaturated zone alternative, but desires funding commitments, a detailed implementation schedule, continued opportunity for involvement, and a faster cleanup. Implementation schedules will be included in post-ROD documents called the Remedial Action Implementation Plan and the Remedial Design/Remedial Action reports. LLNL is continually exploring and implementing new methods and techniques that will accomplish the fastest cleanup.

2.9. The Selected Remedies

Based on the requirements of CERCLA, the detailed analysis of the alternatives, and public comments, DOE, LLNL, EPA, the DTSC of the California Environmental Protection Agency, and the California RWQCB have determined that Alternative No. 1 for ground water (pumping and surface treatment by UV/oxidation and air stripping), and Alternative No. 1 for the

unsaturated zone (vacuum-induced venting and surface treatment of vapors by catalytic oxidation), are the most appropriate remedies for LLNL.

The selected remedies for this site protect human health and the environment, comply with Federal, State, and local requirements (ARARs), are implementable, and permanently and significantly reduce the toxicity, mobility, and volume of the contaminants.

The goal of this remedial action is to remediate ground water to the ARARs specified in the PRAP and this ROD. Based on information obtained during the RI and on a careful analysis of all remedial alternatives, DOE, LLNL, EPA, DTSC, and the RWQCB believe that the selected remedy will achieve this goal. The approach to be taken to the remediation will involve close monitoring of ground water quality in monitor wells, extracted water quality in extraction wells, and water level elevations near the extraction centers. The extraction well field will be operated dynamically to optimize the cleanup. That is, based on the results from the monitoring plan, individual wells may operate continuously, may be turned off, or may be pumped intermittently. During the course of the remediation, new wells will be installed at appropriate locations and will be operated in the same manner.

To ensure that cleanup levels continue to be maintained, the ground water will be monitored until DOE and the regulatory agencies agree that cleanup is complete.

2.9.1. Ground Water

The primary purpose of the selected ground water remedy is to contain VOCs and prevent further downgradient and offsite migration in ground water, and to reduce the concentrations of contaminants in ground water after cleanup to levels below MCLs, the designated cleanup levels. Existing conditions at the site may pose an excess lifetime cancer risk of 2×10^{-3} from ingestion of ground water contaminated with VOCs (primarily TCE) under health-conservative no remediation assumptions. The selected alternative will address all ground water contaminated with VOCs in excess of 5 ppb and will assure that ARARs for individual VOCs, FHCs, lead, chromium, and tritium will be achieved.

The selected ground water remedy involves immediately pumping water at approximately 18 initial locations within the ground water plume (Fig. 7). The total rate of ground water removal for this extraction plan is estimated to be about 350 gpm. Water will be pumped from one or more wells at each of these locations using existing monitor and extraction wells, along with new extraction wells. The well locations will be chosen to prevent any VOCs from escaping from the area in concentrations above their MCLs. To enable more rapid remediation, wells will also be placed in all areas where VOC or FHC concentrations in ground water exceed 100 ppb. Additional extraction locations may be added to ensure complete hydraulic capture of the plume, and/or to expedite cleanup, if field data indicate additional wells are necessary.

Seven onsite facilities (A to G) will be constructed initially to treat the extracted ground water (Fig. 7). Each treatment facility will be designed to treat a somewhat different combination of compounds. Treatment Facilities A, B, E, and F will use UV/oxidation as the primary treatment technology. Treatment Facilities C, D, and G will use air-stripping as the primary treatment technology. All facilities will use GAC to remove VOCs and FHCs from air streams, and Treatment Facility F will use GAC to remove lead from ground water. Treatment Facility D will use ion exchange to remove chromium from ground water.

The maximum additional cancer risk after remediation is complete is calculated at seven in one hundred million (7×10^{-8}) using the best estimate assumptions. This is over 100 times lower than the one in ten thousand to one in ten million (1×10^{-4} to 1×10^{-7}) acceptable level of risk specified in the NCP (U.S. EPA, 1990). The HI for this scenario is far less than 1.0, indicating that no adverse health effects from noncarcinogens would occur following the planned remediation. Using health-conservative assumptions that EPA prescribes for assessing site risks,

the risk of cancer after remediation, based on a potential monitor well drilled 250 feet west of LLNL, is 4×10^{-5} , and 3×10^{-5} for potential receptor wells in downtown Livermore. Both of these values are within the EPA acceptable risk range. The hazard indices for both health-conservative scenarios are far less than 1 (2.7×10^{-2} and 3.1×10^{-2} , respectively), indicating no adverse health affects from noncarcinogens after the planned remediation.

2.9.2. Unsaturated Zone

The selected remedy for the unsaturated zone involves using vacuum-induced venting to extract contaminant vapors from the unsaturated sediments and treating the vapors by catalytic oxidation. Use of a catalytic oxidizer provides the flexibility to treat both FHCs and VOCs together and substantially reduces the potential for producing dioxin. The purpose of this response action is to prevent migration of VOCs and FHCs to ground water in concentrations that would impact the ground water in concentrations above MCLs.

Current data indicate that only FHCs in the Gasoline Spill Area, VOCs in the Building 518 Area in the southeastern part of the LLNL site, and possibly VOCs in the vicinity of the East Taxi Strip in eastern LLNL will need unsaturated zone remediation (Isherwood *et al.*, 1990). FHCs and/or VOCs will be removed from the subsurface by vacuum-induced venting using extraction wells.

The selected treatment option for the extracted vapors is catalytic oxidation. In this process, vapors from vent wells will be heated and passed through a catalyst, where organic compounds are converted to harmless oxidation products, including carbon dioxide and water. If use of catalytic oxidation should result in emission of vapors with compounds above regulatory standards, secondary treatment or alternative technologies, such as GAC, will be evaluated and implemented to comply with regulatory standards.

The decision regarding whether an area requires vadose zone cleanup will be based on unsaturated zone modeling and ground water monitoring. If modeling indicates that hazardous materials will impact ground water in concentrations above an MCL, remediation will be implemented. Remediation will continue until *in situ* concentrations, as verified by soil sampling, are below those predicted to impact ground water above MCLs. In addition, the ground water near the potential source will be monitored for impacts on ground water quality. Details of the modeling and monitoring will be presented in the Remedial Design.

2.10. Statutory Determinations

Section 121 of CERCLA specifies that the selected remedial actions must comply with all Federal and State ARARs, be cost-effective, be protective of human health and the environment, and utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable. In addition, the selected remedies should employ treatment that permanently and significantly reduces the volume, toxicity, or mobility of hazardous wastes as their principal element. The selected remedies for ground water and the unsaturated zone are the same as those described in the PRAP and meet these statutory requirements as discussed below.

2.10.1. Protection of Human Health and the Environment

The selected remedy for ground water will provide adequate protection of human health and the environment through extraction of contaminated ground water and treatment at the surface to reduce *in situ* concentrations below MCLs. Discharges to the air will be designed for no measurable contaminant emissions. In addition, further offsite migration of the contaminant plume will be prevented. The selected remedy will reduce exposure to levels within or below EPA's acceptable carcinogenic risk range of 10^{-4} to 10^{-7} , and hazard indices will be far below 1.0 after cleanup.

Vacuum-induced venting of the unsaturated zone will remove subsurface VOCs and FHCs and prevent contaminant migration to ground water. Implementation of the selected remedies will not pose unacceptable short-term risks or impact the adjacent subsurface media, other than some lowering of water levels due to ground water extraction. Lowering of the water table will be mitigated by locally recharging the ground water with treated ground water.

2.10.2. Compliance with ARARs

The selected remedies will comply with all Federal and State ARARs, including the to be considered (TBC) criteria in Appendix B. Table 1 and Table B-1 in Appendix B list and describe the ARARs and TBCs that will be attained by each selected remedy.

2.10.3. Cost-Effectiveness

The selected remedies provide overall effectiveness proportionate to their costs. Present worth cost estimates for each alternative are presented in Tables 5 and 6. Although the selected remedies cost somewhat more in terms of present worth compared to the other alternatives, they enable more rapid cleanup.

2.10.4. Utilization of Permanent Solutions and Alternative Treatment Technologies to the Maximum Extent Practicable

The selected remedies utilize permanent solutions and alternative treatment technologies to the maximum extent practicable. The selected alternatives permanently remove contaminants from ground water and the unsaturated zone by extraction and treatment at the surface using UV/oxidation, air stripping, GAC, and ion exchange for ground water and catalytic oxidation for vapor. Both selected alternatives provide the best balance of tradeoffs among the alternatives, and use treatment technologies that destroy most contaminants, converting them to harmless compounds.

The selected alternatives will reduce contaminant mobility more than the other alternatives. Although the selected alternatives have a higher present worth cost than the other alternatives, the selected alternatives will accomplish the cleanup objectives in a shorter time period. Therefore, reducing contaminant mobility and expediting cleanup time (short-term effectiveness) were the most important primary balancing criteria in selecting the remedies.

For both selected alternatives, overall protection of human health and the environment and the compliance with ARARs were also decisive factors in remedy selection. Community concerns were included in the decision-making process by addressing community input received at CWG meetings and during the public comment period on the PRAP. The Responsiveness Summary, attached to this ROD, addresses community comments on the remedial alternatives.

2.10.5. Preference for Treatment as a Principal Element

The selected remedial actions satisfy the statutory preference for selecting remedies in which treatment that permanently and significantly reduces the volume, toxicity or mobility of the contaminants is a principal element. The selected remedial action for ground water uses treatment to address the contaminated ground water, which is the principal medium of concern. UV/oxidation-based technology destroys contaminants leaving residual harmless compounds such as carbon dioxide and water. Both UV/oxidation and air stripping-based technologies will achieve a permanent and significant reduction of the toxicity, mobility, or volume of the contaminants. Similarly, for the unsaturated zone, vacuum-induced venting followed by catalytic oxidation of the extracted vapor will destroy VOCs and FHCs after removal from contaminated soil, thereby also meeting this statutory preference.

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Appendix A

**Tables Summarizing
Predicted Cancer Risks and
Hazard Quotients for
Offsite Exposure**

Table A-1. Predicted cancer risks for the best-estimate exposure scenario based on EPA methodology.

Receptor location ^a	Chemical	Predicted concentration ^b (mg/L)	Oral intake (mg/kg-d)	Oral cancer risk	Inhalation cancer risk	EPA total cancer risk
<i>Maximum chloroform concentration</i>						
	Chloroform	1.5×10^{-4}	4.3×10^{-6}	3×10^{-8}	3×10^{-7}	4×10^{-7}
<i>Maximum TCE concentration</i>						
	TCE	1.0×10^{-4}	2.9×10^{-6}	3×10^{-8}	4×10^{-8}	7×10^{-8}
	1,1-DCE	5.6×10^{-6}	1.6×10^{-7}	1×10^{-7}	2×10^{-7}	3×10^{-7}
	Carbon tetrachloride	4.4×10^{-6}	1.3×10^{-7}	2×10^{-8}	2×10^{-8}	4×10^{-8}
					Sum =	4×10^{-7}
<i>Maximum 1,1-DCE and carbon tetrachloride concentrations</i>						
	TCE	8.0×10^{-5}	2.3×10^{-6}	2×10^{-8}	3×10^{-8}	5×10^{-8}
	Chloroform	1.0×10^{-5}	2.9×10^{-7}	2×10^{-9}	2×10^{-8}	2×10^{-8}
	1,1-DCE	1.1×10^{-5}	3.1×10^{-7}	2×10^{-7}	4×10^{-7}	6×10^{-7}
	Carbon tetrachloride	9.0×10^{-6}	2.6×10^{-7}	3×10^{-8}	3×10^{-8}	6×10^{-8}
					Sum =	7×10^{-7}
<i>Maximum PCE concentration</i>						
	PCE	1.0×10^{-5}	2.9×10^{-7}	1×10^{-8}	9×10^{-10}	2×10^{-8}

^a All receptor wells are 2 miles west of LLNL.^b Predicted maximum ground water concentrations have been reduced by a factor of ten to account for in-well dilution that would occur because the municipal well would draw water from both contaminated and uncontaminated zones.

Table A-2. Predicted cancer risks for the health-conservative exposure scenario based on EPA methodology.

Receptor location	Chemical	Predicted concentration (mg/L)	Oral intake (mg/kg-d)	Oral cancer risk	Inhalation cancer risk	EPA total cancer risk
<u>250 feet west of LLNL</u>						
<i>Maximum chloroform concentration</i>						
	PCE	6.2×10^{-3}	1.8×10^{-4}	9×10^{-6}	6×10^{-7}	1×10^{-5}
	TCE	2.6×10^{-1}	7.4×10^{-3}	8×10^{-5}	1×10^{-4}	2×10^{-4}
	Chloroform	5.5×10^{-2}	1.6×10^{-3}	1×10^{-5}	1×10^{-4}	1×10^{-4}
	1,1-DCE	1.0×10^{-2}	2.9×10^{-4}	2×10^{-4}	3×10^{-4}	5×10^{-4}
	Carbon tetrachloride	7.9×10^{-3}	2.3×10^{-4}	3×10^{-5}	3×10^{-5}	6×10^{-5}
					Sum =	9×10^{-4}
<i>Maximum TCE, 1,1-DCE, and carbon tetrachloride concentrations</i>						
	PCE	5.2×10^{-2}	1.5×10^{-3}	8×10^{-5}	5×10^{-6}	8×10^{-5}
	TCE	4.7×10^{-1}	1.3×10^{-2}	1×10^{-4}	2×10^{-4}	3×10^{-4}
	Chloroform	2.0×10^{-2}	5.7×10^{-4}	3×10^{-6}	5×10^{-5}	5×10^{-5}
	1,1-DCE	2.4×10^{-2}	6.7×10^{-4}	4×10^{-4}	8×10^{-4}	1×10^{-3}
	Carbon tetrachloride	1.8×10^{-2}	5.3×10^{-4}	7×10^{-5}	7×10^{-5}	1×10^{-4}
					Sum =	2×10^{-3}
<i>Maximum PCE concentration</i>						
	PCE	2.7×10^{-1}	7.7×10^{-3}	4×10^{-4}	3×10^{-5}	4×10^{-4}
	TCE	6.2×10^{-2}	1.8×10^{-3}	2×10^{-5}	2×10^{-5}	4×10^{-5}
	Chloroform	8.2×10^{-3}	2.3×10^{-4}	1×10^{-6}	2×10^{-5}	2×10^{-5}
	1,1-DCE	1.4×10^{-2}	4.0×10^{-4}	2×10^{-4}	5×10^{-4}	7×10^{-4}
	Carbon tetrachloride	1.1×10^{-2}	3.1×10^{-4}	4×10^{-5}	4×10^{-5}	8×10^{-5}
					Sum =	1×10^{-3}

Table A-2. (Continued)

Receptor location	Chemical	Predicted concentration (mg/L)	Oral intake (mg/kg-d)	Oral cancer risk	Inhalation cancer risk	EPA total cancer risk
<u>1 mile west of LLNL</u>						
<i>Maximum chloroform concentration</i>						
	PCE	5.9×10^{-3}	1.7×10^{-4}	9×10^{-6}	6×10^{-7}	9×10^{-6}
	TCE	2.4×10^{-1}	6.9×10^{-3}	8×10^{-5}	9×10^{-5}	2×10^{-4}
	Chloroform	4.9×10^{-2}	1.4×10^{-3}	9×10^{-6}	1×10^{-4}	1×10^{-4}
	1,1-DCE	1.0×10^{-2}	2.9×10^{-4}	2×10^{-4}	3×10^{-4}	5×10^{-4}
	Carbon tetrachloride	7.9×10^{-3}	2.3×10^{-4}	3×10^{-5}	3×10^{-5}	6×10^{-5}
					Sum =	9×10^{-4}
<i>Maximum TCE, 1,1-DCE, and carbon tetrachloride concentrations</i>						
	PCE	5.2×10^{-2}	1.5×10^{-3}	8×10^{-5}	5×10^{-6}	8×10^{-5}
	TCE	3.8×10^{-1}	1.1×10^{-2}	1×10^{-4}	1×10^{-4}	3×10^{-4}
	Chloroform	1.7×10^{-2}	4.9×10^{-4}	3×10^{-6}	4×10^{-5}	4×10^{-5}
	1,1-DCE	2.2×10^{-2}	6.4×10^{-4}	4×10^{-4}	8×10^{-4}	1×10^{-3}
	Carbon tetrachloride	1.8×10^{-2}	5.0×10^{-4}	7×10^{-5}	7×10^{-5}	1×10^{-4}
					Sum =	2×10^{-3}
<i>Maximum PCE concentration</i>						
	PCE	2.1×10^{-1}	6.0×10^{-3}	3×10^{-4}	2×10^{-5}	3×10^{-4}
	TCE	5.8×10^{-2}	1.7×10^{-3}	2×10^{-5}	2×10^{-5}	4×10^{-5}
	Chloroform	7.3×10^{-3}	2.1×10^{-4}	1×10^{-6}	2×10^{-5}	2×10^{-5}
	1,1-DCE	1.5×10^{-2}	4.2×10^{-4}	2×10^{-4}	5×10^{-4}	7×10^{-4}
	Carbon tetrachloride	1.1×10^{-3}	3.3×10^{-4}	4×10^{-5}	4×10^{-5}	9×10^{-5}
					Sum =	1×10^{-3}

Table A-2. (Continued)

Receptor location	Chemical	Predicted concentration (mg/L)	Oral intake (mg/kg-d)	Oral cancer risk	Inhalation cancer risk	EPA total cancer risk
<i>2 miles west of LLNL</i>						
<i>Maximum chloroform concentration</i>						
	PCE	6.1×10^{-3}	1.7×10^{-4}	9×10^{-6}	6×10^{-7}	9×10^{-6}
	TCE	2.3×10^{-1}	6.6×10^{-3}	7×10^{-5}	9×10^{-5}	2×10^{-4}
	Chloroform	4.5×10^{-2}	1.3×10^{-3}	8×10^{-6}	1×10^{-4}	1×10^{-4}
	1,1-DCE	1.0×10^{-2}	2.9×10^{-4}	2×10^{-4}	3×10^{-4}	5×10^{-4}
	Carbon tetrachloride	7.9×10^{-3}	2.3×10^{-4}	3×10^{-5}	3×10^{-5}	6×10^{-5}
					Sum =	9×10^{-4}
<i>Maximum TCE, 1,1-DCE, and carbon tetrachloride concentrations</i>						
	PCE	4.9×10^{-2}	1.4×10^{-3}	7×10^{-5}	5×10^{-6}	8×10^{-5}
	TCE	3.4×10^{-1}	9.7×10^{-3}	1×10^{-4}	1×10^{-4}	2×10^{-4}
	Chloroform	1.6×10^{-2}	4.6×10^{-4}	3×10^{-6}	4×10^{-5}	4×10^{-5}
	1,1-DCE	2.0×10^{-2}	5.6×10^{-4}	3×10^{-4}	7×10^{-4}	1×10^{-3}
	Carbon tetrachloride	1.5×10^{-2}	4.4×10^{-4}	6×10^{-5}	6×10^{-5}	1×10^{-4}
					Sum =	1×10^{-3}
<i>Maximum PCE concentration</i>						
	PCE	1.7×10^{-1}	4.9×10^{-3}	2×10^{-4}	2×10^{-5}	3×10^{-4}
	TCE	5.6×10^{-2}	1.6×10^{-3}	2×10^{-5}	2×10^{-5}	4×10^{-5}
	Chloroform	6.9×10^{-3}	2.0×10^{-4}	1×10^{-6}	2×10^{-5}	2×10^{-5}
	1,1-DCE	1.3×10^{-2}	3.8×10^{-4}	2×10^{-4}	5×10^{-4}	7×10^{-4}
	Carbon tetrachloride	1.1×10^{-3}	3.0×10^{-4}	4×10^{-5}	4×10^{-5}	8×10^{-5}
					Sum =	1×10^{-3}

Table A-3. Calculation of the noncarcinogenic hazard index for the best-estimate exposure scenario.

Observation point ^a	Chemical	Predicted concentration ^b (mg/L)	Water ingestion (mg/kg-d)	EPA hazard index (exposure/Rfd)
<i>Maximum chloroform concentration</i>	Chloroform	1.5×10^{-4}	4.3×10^{-6}	4.3×10^{-4}
<i>Maximum TCE concentration</i>	TCE	1.0×10^{-4}	2.9×10^{-6}	NA
	1,1-DCE	5.6×10^{-6}	1.6×10^{-7}	1.8×10^{-5}
	Carbon tetrachloride	4.4×10^{-6}	1.3×10^{-7}	1.8×10^{-4}
			Sum =	2.0×10^{-4}
<i>Maximum carbon tetrachloride and 1,1-DCE concentrations</i>	Chloroform	2.0×10^{-5}	5.7×10^{-7}	5.7×10^{-5}
	1,1-DCE	4.5×10^{-5}	1.3×10^{-6}	1.4×10^{-4}
	Carbon tetrachloride	3.5×10^{-5}	1.0×10^{-7}	1.4×10^{-3}
			Sum =	1.6×10^{-3}
<i>Maximum PCE concentration</i>	PCE	1.0×10^{-5}	2.9×10^{-7}	2.9×10^{-5}

NA = Not available.

^a All receptor wells are 2 miles west of LLNL.^b Predicted maximum ground water concentrations have been reduced by a factor of ten to account for in-well dilution that would occur because the municipal well would draw water from both contaminated and uncontaminated zones.

Table A-4. Calculation of the noncarcinogenic hazard index for the health-conservative exposure scenario.

Observation point	Chemical	Predicted concentration (mg/L)	Water ingestion (mg/kg-d)	EPA hazard index (exposure/RFD)
<u>Well 250 feet west of LLNL</u>				
Maximum chloroform concentration	PCE	6.2×10^{-3}	1.8×10^{-4}	2×10^{-2}
	TCE	2.6×10^{-1}	7.4×10^{-3}	NA
	Chloroform	5.5×10^{-2}	1.6×10^{-3}	2×10^{-1}
	1,1-DCE	1.0×10^{-2}	2.9×10^{-4}	3×10^{-2}
	Carbon tetrachloride	7.9×10^{-3}	2.3×10^{-4}	<u>3×10^{-1}</u>
			Sum =	5×10^{-1}
Maximum TCE, 1,1-DCE, and carbon tetrachloride concentrations	PCE	5.2×10^{-2}	1.5×10^{-3}	1×10^{-1}
	TCE	4.7×10^{-1}	1.3×10^{-2}	NA
	Chloroform	2.0×10^{-2}	5.7×10^{-4}	6×10^{-2}
	1,1-DCE	2.4×10^{-2}	6.7×10^{-4}	7×10^{-2}
	Carbon tetrachloride	1.8×10^{-2}	5.3×10^{-4}	<u>8×10^{-1}</u>
			Sum =	1×10^0
Maximum PCE concentration	PCE	2.7×10^{-1}	7.7×10^{-3}	8×10^{-1}
	TCE	6.2×10^{-2}	1.8×10^{-3}	NA
	Chloroform	8.2×10^{-3}	2.3×10^{-4}	2×10^{-2}
	1,1-DCE	1.4×10^{-2}	4.0×10^{-4}	4×10^{-2}
	Carbon tetrachloride	1.1×10^{-2}	3.1×10^{-4}	<u>4×10^{-1}</u>
			Sum =	1×10^0
<u>Well 1 mile west of LLNL</u>				
Maximum chloroform concentration	PCE	5.9×10^{-3}	1.7×10^{-4}	2×10^{-2}
	TCE	2.4×10^{-1}	6.9×10^{-3}	NA
	Chloroform	4.9×10^{-2}	1.4×10^{-3}	1×10^{-1}
	1,1-DCE	1.0×10^{-2}	2.9×10^{-4}	3×10^{-2}
	Carbon tetrachloride	7.9×10^{-3}	2.3×10^{-4}	<u>3×10^{-1}</u>
			Sum =	5×10^{-1}

Table A-4. (Continued)

Observation point	Chemical	Predicted concentration (mg/L)	Water ingestion (mg/kg-d)	EPA hazard index (exposure/RFD)
<i>Maximum TCE, 1,1-DCE, and carbon tetrachloride concentrations</i>	PCE	5.2×10^{-2}	1.5×10^{-3}	1×10^{-1}
	TCE	3.8×10^{-1}	1.1×10^{-2}	NA
	Chloroform	1.7×10^{-2}	4.9×10^{-4}	5×10^{-2}
	1,1-DCE	2.2×10^{-2}	6.4×10^{-4}	7×10^{-2}
	Carbon tetrachloride	1.8×10^{-2}	5.0×10^{-4}	7×10^{-1}
	Sum =			1×10^0
<i>Maximum PCE concentration</i>	PCE	2.1×10^{-1}	6.0×10^{-3}	6×10^{-1}
	TCE	5.8×10^{-2}	1.7×10^{-3}	NA
	Chloroform	7.3×10^{-3}	2.1×10^{-4}	2×10^{-2}
	1,1-DCE	1.5×10^{-2}	4.2×10^{-4}	5×10^{-2}
	Carbon tetrachloride	1.1×10^{-2}	3.3×10^{-4}	5×10^{-1}
	Sum =			1×10^0
<u><i>Well 2 miles west of LLNL</i></u>				
<i>Maximum chloroform concentrations</i>	PCE	6.1×10^{-3}	1.7×10^{-4}	2×10^{-2}
	TCE	2.3×10^{-1}	6.6×10^{-3}	NA
	Chloroform	4.5×10^{-2}	1.3×10^{-3}	1×10^{-1}
	1,1-DCE	1.0×10^{-2}	3.2×10^{-4}	3×10^{-2}
	Carbon tetrachloride	7.9×10^{-3}	1.9×10^{-4}	3×10^{-1}
	Sum =			5×10^{-1}
<i>Maximum TCE, 1,1-DCE, and carbon tetrachloride concentrations</i>	PCE	4.9×10^{-2}	1.4×10^{-3}	1×10^{-1}
	TCE	3.4×10^{-1}	9.7×10^{-3}	NA
	Chloroform	1.6×10^{-2}	4.6×10^{-4}	5×10^{-2}
	1,1-DCE	2.0×10^{-2}	5.6×10^{-4}	6×10^{-2}
	Carbon tetrachloride	1.5×10^{-2}	4.4×10^{-4}	6×10^{-1}
	Sum =			9×10^{-1}
<i>Maximum TCE, 1,1-DCE, and carbon tetrachloride concentrations</i>	PCE	1.7×10^{-1}	4.9×10^{-3}	5×10^{-1}
	TCE	5.6×10^{-2}	1.6×10^{-3}	NA
	Chloroform	6.9×10^{-3}	2.0×10^{-4}	2×10^{-2}
	1,1-DCE	1.3×10^{-2}	3.8×10^{-4}	4×10^{-2}
	Carbon tetrachloride	1.1×10^{-2}	3.0×10^{-4}	4×10^{-1}
	Sum =			1×10^0

Appendix B
LLNL ARARs

Appendix B

LLNL ARARs

This Appendix discusses those standards, requirements, criteria, or limitations under Federal environmental law, and any promulgated standards, requirements, criteria, or limitations under State environmental or facility siting law that are more stringent than those provided under Federal law, that the signatories to LLNL's Federal Facility Agreement consider legally applicable or relevant and appropriate to the LLNL site. In addition, nonpromulgated criteria advisories or guidance that do not meet the definition of Applicable or Relevant and Appropriate Requirements (ARARs), but that may assist in determining what is necessary to be protective, are listed as to be considered. (TBC). Some of these apply to remediation activities, such as discharges from treatment facilities, whereas others form the basis for determining when cleanup is complete. Table B-1 is a summary of corresponding ARARs for ground water and the vadose zone. A complete discussion of LLNL ARARs is presented in Section 3 of the Feasibility Study (FS) (Isherwood *et al.*, 1990).

There are three general kinds of ARARs: chemical-specific, location-specific, and action-specific. Chemical-specific ARARs usually result in health- or risk-based concentration limits. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) *Compliance with Other Laws Manual* (U.S. EPA, 1988b) contains a nonexhaustive list of potential chemical-specific ARARs from which LLNL has drawn to ensure that no ARAR is overlooked.

The chemical-specific concentrations proposed as remedial action objectives for ground water remediation are given for the compounds of concern at LLNL in Table 1 of this document. The standards in the columns of Federal and State drinking water Maximum Contaminant Levels (MCLs) and Federal non-zero Maximum Containment Levels Goals become remedial action objectives for ambient ground water (i.e., ground water left in place after remediation), whereas the discharge limits given in the last column apply to discharges of treated water under LLNL's National Pollution Discharge Elimination System permit. The most stringent concentration limit is the governing ARAR for each chemical of concern.

San Francisco Bay Area Regional Water Quality Control Board's Basin Plan ("Basin Plan") taste and odor objectives are not considered an ARAR because acceptable numerical expressions of these objectives are not available at the present time. There is no methodology for enforcement of these objectives and consequently they have not been enforced by the State. We, therefore, cannot use the Basin Plan's taste and odor objectives to establish a cleanup level for compliance purposes. If in the future a method is established for measurement and achievement of the Basin Plan's taste and odor objectives and achievement of those objectives is determined to be applicable or relevant and appropriate and necessary to ensure that the remedy is protective of human health and the environment, then LLNL will consider the objectives applicable to the cleanup.

If any additional hazardous substances are found in the ground water environment at levels of concern in the future, standards for those will be requested and agreed upon with the U.S. Environmental Protection Agency and the California Department of Toxic Substances Control.

Resource Conservation Recovery Act (RCRA) Section 3020 bans hazardous disposal by underground injection into or above a source of drinking water unless the reinjection involves treated ground water from a CERCLA response action. This section does not apply if certain conditions are met. At LLNL, proposed injection is a CERCLA response

action intended to clean up contamination; the contaminated ground water will be treated to substantially reduce hazardous constituents prior to such injection; and the response action will be sufficient to protect human health and the environment upon completion. LLNL thus meets the conditions for exemption and is not subject to the ban.

Whereas specific ARARs do not appear to exist as cleanup standards for vadose zone sediments, LLNL considers health protection (at a 10^{-6} risk) to be a remedial action objective. Based on results of the Baseline Public Health Assessment (BPHA), ground water constitutes the only significant pathway of exposure from vadose zone contaminants. The BPHA demonstrates that, if ground water concentrations are at MCLs or below, the health risk is well below 10^{-6} .

Unsaturated sediment cleanup concentrations will be based on the mobility of specific contaminants in the sediment at the LLNL site. We have examined the potential for hazardous substances in the sediments of the unsaturated zone to migrate to ground water (Appendix G of the FS). The preliminary results of our investigation indicate that the potential for affecting the ground water depends on the mass, concentration, and distribution of contaminants in the vadose zone.

For the areas of greatest potential concern at LLNL, we conclude that the dominant transport mechanism for migration to the ground water is vapor diffusion. The model illustrated in Appendix G of the FS provides a basis for deciding which, if any, areas at LLNL may warrant vadose zone remediation.

Based on the findings of the BPHA section of the Remedial Investigation (RI) (Thorpe *et al.*, 1990) that no surficial soils at LLNL constitute a potential health threat, we have no cleanup standards for surficial soils.

Location-specific ARARs are restrictions placed on the concentration of chemicals or conduct of operations based on the location of a site. Potential location-specific ARARs include the protection of:

- Wetlands.
- Floodplains.
- Historic landmarks.
- Coastal zones.
- Coastal barriers.
- Rare and endangered species.
- Cultural resources.

The LLNL site contains no floodplains, historic landmarks, coastal zones, or coastal barriers. As stated in the Livermore Site Environmental Impact Report (EIR) (DOE and University of California, 1992), three small wetlands exist at the culverts that channel runoff into Arroyo Las Positas at the northern perimeter of the site. A review of the LLNL site for rare and endangered species was performed as part of the site EIR, and none have been found. No contemplated action will have an impact beyond those discussed in Section 5 of the FS. LLNL does not believe that significant cultural resources will be impacted, because (1) there is no source of water on the site to sustain early cultures, and (2) virtually the entire site has been subject to intense development over the last 50 years. No excavation is contemplated that would disturb sites to depths greater than they may have already been disturbed.

California's Alquist-Priolo Special Studies Zones Act of 1972 (California Public Resource Code, Section 2621, *et seq.*) provides constraints on the building of residences

within 50 feet of an active fault. RCRA 40 CFR Section 264.18(a) prohibits new treatment, storage, or disposal facilities within 200 feet of a Holocene fault. There are no active faults within 200 feet of LLNL, and construction of residences is not permitted onsite; therefore, these two requirements are not ARARs. All treatment facilities will comply with local construction codes as applied by LLNL's Plant Engineering Department.

Action-specific ARARs are usually technology- or activity-based limitations on actions taken with respect to hazardous wastes. These requirements are triggered by the particular remedial activities that are selected to accomplish a remedy. Since there are usually several alternative actions for any remedial site, different requirements can be triggered. Action-specific ARARs may indicate or influence how a selective alternative is implemented.

The ARARs for the LLNL Livermore site are summarized in Table B-1.

Table B-1. Federal and State and local ARARs for LLNL (modified from Chapter 3 of the LLNL FS).

		Media to be remediated ^a	Applicable, (A)	Relevant and Appropriate (RAR)	To be considered (TBC)
Comments					
Federal Chemical-Specific Requirements					
Safe Drinking Water Act (SDWA) [42 USCA 300] [40 CFR 141.11–141.16; 141.50–141.51]	This law establishes treatment standards for current potential drinking water sources by setting Maximum Contaminant Levels (MCLs) and non-zero Maximum Contaminant Level Goals (MCLGs), which are used as cleanup standards. Those standards for the LLNL site are listed in Table 1 of the ROD.	GW, VZ	x ^b	x ^b x ^b	
Clean Air Act (CAA) [42 USCA 7401–7442] [40 CFR 50–69]	National primary and secondary ambient air quality standards (NAAQS) are defined under Section 109 of the CAA and are listed in 40 CFR 50.	GW, VZ	x ^c x ^c		
Clean Air Act [42 USCA 7412] [40 CFR 61.92]	National Emission Standards for Hazardous Air Pollutants (NESHAPs) are specific to industrial emissions. 40 CFR 61.92 limits emissions of radionuclides to those amounts that would cause any member of the public to receive, in any one year, a maximum effective dose equivalent of 10 millirem per year.	GW, VZ	x ^c x ^c		
Federal Action-Specific Requirements					
Action: Closure					
Resource Conservation Recovery Act (RCRA) 42 USCA 6901 [40 CFR 264.111]	Requires that a facility be closed in a manner which minimizes the need for further maintenance and is protective of human health and the environment. Applicable to hazardous waste management facilities.	GW, VZ	x ^b x ^b		
RCRA [40 CFR 264.178]	Requires removal of all hazardous waste and waste residues from containment systems. Although the treatment facilities and thermal system are not considered containment systems, this closure requirement will be considered RAR.	GW, VZ		x ^b x ^b	

Table B-1. (Continued)

Comments		Media to be remediated ^a	Applicable (A)	Relevant and Appropriate (RAR)	To be considered (TBC)
<i>Action: Pump and Treat</i>					
RCRA [40 CFR 264.190-192]	Design and operating standards for tank systems. Tank systems may be used for pump and treat alternatives.	GW, VZ	X ^b X ^b		
RCRA [40 CFR 264.601-602]	Design, monitoring, and performance standards for miscellaneous treatment units.	GW, VZ	X ^b X ^b		
Land Disposal Restrictions (LDRs) RCRA [40 CFR 268]	Any waste placed in land-disposal units must comply with LDRs by either attaining specific performance or technology-based standards. This is applicable to untreated soil or debris from the CERCLA cleanup.	GW, VZ	X ^b X ^b		
<i>Action: Thermal Treatment</i>					
RCRA [40 CFR 265.373-381]	These regulations apply to owners or operators of facilities that thermally treat hazardous waste in devices other than enclosed devices that use controlled flame combustion.	VZ	X ^b		
<i>Action: Transportation</i>					
Transportation of Hazardous Waste RCRA [40 CFR 263]	Transporters must be licensed hazardous waste haulers. In the event of a discharge during transportation, the transporter must take immediate action to protect human health and the environment (263.30) and clean up the discharge such that it no longer presents a hazard (263.31). Generated waste being transported to an offsite disposal facility would be subject to this requirement.	GW, VZ	X ^b X ^b		
<i>Action: Reinjection of Treated Ground Water</i>					
Safe Drinking Water Act Underground Injection Control Program [40 CFR 144.26-27] [40 CFR 146.51-52]	These regulations consist of inventory and monitoring requirements for reinjection of treated ground water.	GW, VZ	X ^b X ^b		

Table B-1. (Continued)

Comments		Media to be remediated ^a	Applicable (A)	Relevant and Appropriate (RAR)	To be considered (TBC)
Action: Discharge of Treatment System Effluent					
Clean Water Act (CWA) [33 USCA 1251-1376] National Pollutant Discharge Elimination System (NPDES) [40 CFR 122-125]	Both onsite and offsite discharges from CERCLA sites to surface waters are required to meet the substantive CWA limitations, monitoring requirements [40 CFR 122.41(i); 40 CFR 136.1; 40 CFR 136.4], and best management practices [40 CFR 125.100].	GW, VZ	x ^d x ^d		
Action: Air Stripping					
OSWER Directive 9355.0-28	Establishes guidance on the control of air emissions from air strippers used at Superfund sites for ground water treatment. This is a nonpromulgated directive and is, therefore, TBC.	GW, VZ			x ^e x ^e
General Action-Specific TBCs.					
DOE Order 5400.4	Prescribes conduct of operations on DOE facilities for compliance with CERCLA, and provides for the integration of NEPA and CERCLA documentation for DOE. This is a nonpromulgated regulation and is, therefore, TBC.	GW, VZ			x ^d x ^d
State and Local Chemical- Specific Requirements					
Hazardous Waste Control Act (HCWA) (Health and Safety Code, Section 25100- 25395), CCR, Title 22, ch. 30: Minimum Standards for Management of Hazardous and Extremely Hazardous Wastes	HCWA controls hazardous wastes from their point of generation through accumulation, transportation, treatment, storage, and ultimate disposal. All potentially hazardous materials are handled in accordance with standard chain-of- custody procedures.	GW, VZ	x ^b x ^b		

Table B-1. (Continued)

	Comments	Media to be remediated ^a	Applicable (A)	Relevant and Appropriate (RAR)	To be considered (TBC)
Criteria for Identifying Hazardous Wastes [Title 22, 66693-66776]	Tests for identifying hazardous characteristics are set forth in these regulations. If a chemical is either listed or tested and found hazardous, then remedial actions must comply with Title 22 requirements.	GW, VZ	X ^b X ^b		
California Safe Drinking Water Act, Health and Safety Code, Section 2549.5	Regulations and standards for public water systems; MCLs and secondary MCLs (SMCLs), which are enforceable in California; requirements for water quality analyses and laboratories.	GW, VZ		X ^b X ^b	
Persistent and Bioaccumulative Toxic Substances [Title 22, 66699]	Total Threshold Limit Concentrations (TTLCs) and Soluble Threshold Limit Concentrations (STLCs) have been established for selected toxics to be used in establishing whether waste is hazardous. If a chemical is either listed or tested and found hazardous, then remedial actions must comply with the hazardous waste requirements under Title 22.	GW, VZ	X ^b X ^b		
Porter-Cologne Water Quality Control Act [WC13000-13806], as administered by the State Water Resources Control Board (SWRCB) and the Regional Water Quality Control Board (RWQCB) under CCR Title 23, subch. 15, 1050-2836.	Establishes authority for State and Regional Water Boards to determine site-specific discharge requirements and to regulate disposal of waste to land.	GW, VZ	X ^b X ^b		
State Water Resources Control Board's Resolution 68-16	The State Board's policy on maintaining the high quality of California's waters implies that ground water cleanup should continue below MCLs if it can be shown that it is technically feasible and cost effective to do so.	GW, VZ	X ^b X ^b		

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Table B-1. (Continued)

	Comments	Media to be remediated ^a	Applicable (A)	Relevant and Appropriate (RAR)	To be considered (TBC)
29 USC 651 <i>et seq.</i> Occupational Safety and Health Act (OSHA)	OSHA requirements under 29 CFR 1910.120 are applicable to worker exposures during response actions at CERCLA sites; 29 CFR 1926 construction standards apply during construction phase of treatment facilities.	GW, VZ	X ^b X ^b		
29 CFR 1910 <i>et seq.</i> Noise Control Act of 1972, as amended by the Quiet Communities Act of 1978 [40 CFR 204, 205, 211] <i>State and Local Action-Specific Requirements</i> <i>Action: General Treatment of Hazardous Waste</i>	Construction and transportation equipment noise levels (e.g., portable air compressors, and medium and heavy trucks), process equipment noise levels, and noise levels at the property boundaries of the project are regulated under this Act. State or local agencies typically enforce these levels.	GW, VZ	X ^b X ^b		
Hazardous Waste Control Act, Health and Safety Code (HSCWA), Sections 25100–25395 [22 CCR 67100–67195]	Requirements for general operations of interim status and permitted facilities [67100–67108], including preparedness and prevention [67120–67126], contingency plans and emergency procedures [67140–67145], and manifesting and monitoring requirements [67180–67195].	GW, VZ	X ^b X ^b		
Hazardous Waste Control Act Land-Disposal Restrictions [22 CCR 66900]	This law requires that certain hazardous wastes meet minimum treatment standards prior to disposal at a landfill.	GW, VZ	X ^b X ^b		
Hazardous Materials Release Response Plans and Inventory [H&SC, Div. 20, ch. 6.95] [19 CCR, ch. 3, subch. 3]	This law requires businesses handling hazardous materials to plan for emergency response actions.	GW, VZ	X ^b X ^b		

Table B-1. (Continued)

Comments		Media to be remediated ^a	Applicable (A)	Relevant and Appropriate (RAR)	To be considered (TBC)
Action: Closure					
Hazardous Waste Control Act Closure Requirements, Sections 25100-25395 [22 CCR 67210-67220]	A facility shall be closed in a manner that minimizes the need for future maintenance. If hazardous wastes are left in place, postclosure care must continue for 30 years.	GW, VZ	X ^b X ^b		
Action: Transportation					
Hazardous Waste Control Act Hauler Registration Requirements [22 CCR 66420-66465] and Requirements for Transporters of Hazardous Waste [22 CCR 66530-66564]	Hazardous wastes must be transported by a hauler registered with the State of California.	GW, VZ	X ^b X ^b		
Requirements for Generators of Hazardous Waste [Title 22 66470-66515]	Owners or operators who ship hazardous waste from a Transport, Storage, or Disposal (TSD) facility shall comply with the generator standards in these regulations. These standards include keeping of manifests [66481], submission of manifest to CDHS within 30 days of shipment [66484(f)], preparation of a biennial report [66493(a)], and a maximum 90-day accumulation time [66508(a)]. These regulations are applicable to transportation and offsite disposal of hazardous waste.	GW, VZ	X ^b X ^b		
Action: Discharge of Treatment System Effluent					

Table B-1. (Continued)

Comments		Media to be remediated ^a	Applicable (A)	Relevant and Appropriate (RAR)	To be considered (TBC)
Porter-Cologne Water Quality Control Act [WC 13000–13806], as administered by the State Water Resources Control Board (SWRCB) and the Regional Water Quality Control Board (RWQCB) under CCR Title 23, subch. 15, 1050–2836	Establishes authority for State and Regional Water Boards to determine site-specific discharge requirements and to regulate disposal of waste to land.	GW, VZ	X ^b X ^b		
Fish and Game Regulations on Pollution <i>Action: Air Stripping</i>	Prohibits water pollution with any substance or material deleterious to fish, plant, or bird life.	GW, VZ	X ^f X ^f		
Air Resources Act (Health and Safety Code, section 3900 <i>et. seq.</i>)	Establishes allowable discharge standards for point sources within each air pollution control district, and establishes ambient air quality standards.	GW, VZ	X ^b X ^b		
Bay Area Air Quality Management District [Regulation 8, Rule 47]	Requires permitting of VOC air discharges (e.g., from an air-stripping unit).	GW, VZ	X ^b X ^b		
<i>Location-Specific Requirements</i>	There are no Federal or State location-specific requirements for the LLNL site.				

a GW —Pump and treat; complete hydraulic capture with source remediation.

VZ —Vacuum-induced venting with catalytic oxidations.

b All RARs are the same for all treatment options contemplated under this treatment alternative.

c CAA requirements only apply to treatment options with atmospheric discharges.

d Only offsite CERCLA discharges to surface waters must be NPDES-permitted.

e Factors TBC are the same for all treatment options contemplated under this treatment alternative.

f Applies only to treatment options with surface discharges.